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ABSTRACT

This document describes the Exploratorium Framework project which is a model initiative demonstrating the vital role science museums play in science education reform. Contents include: (1) "The Four Thematic Exhibit Experiments (An Overview)"; (2) "Themes (Looking at the World through Theme-Colored Glasses)"; (3) "Creating an Environment (Don't Fence Me In?)"; (4) "Audience (Whoever Walks in the Door?)"; (5) "Staff-Visitor Interactions (The Human Element)"; (6) "Teachers (Bridging the Formal-Informal Gap)"; (7) "Politics (Trickle Up; Trickle Down)"; and (8) "Personal Perspectives". (YDS)

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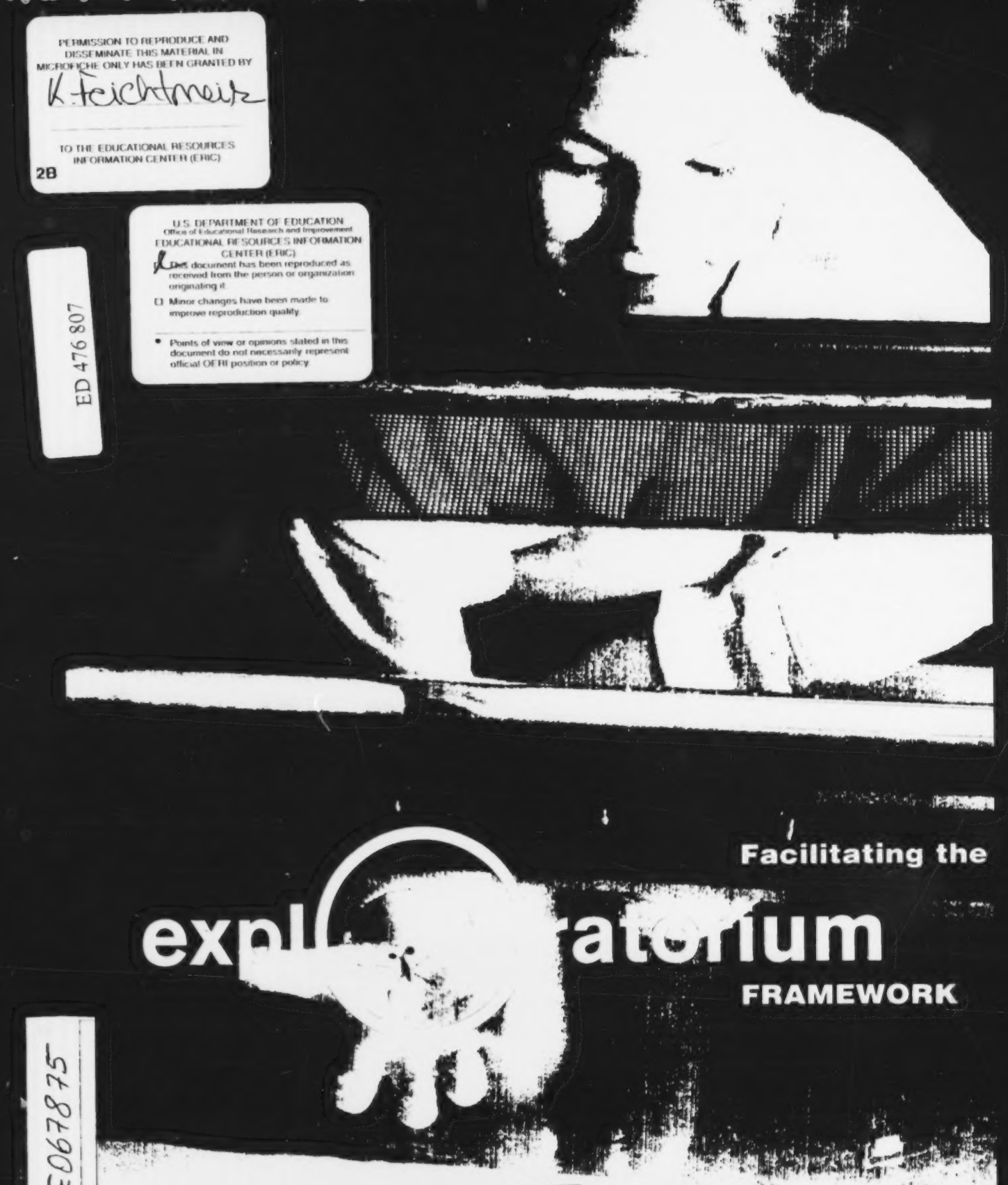

Facilitating the exploratorium FRAMEWORK

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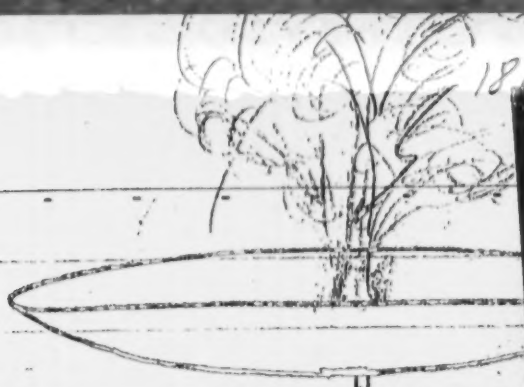

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INTRODUCTION

In 1994, the Exploratorium launched the Framework project, a model initiative designed to demonstrate the vital role science museum exhibits could play in supporting science education reform. Funded by the National Science Foundation (NSF), the project was designed to accomplish the following:

- Develop four new exhibit collections based on the themes in the *Science Framework for California Public Schools*.
- Experiment with the physical arrangement of exhibits to determine the most effective configurations for teachers, students, and the public.
- Create a wide variety of supporting materials, including multilingual introductory panels, an interactive reference kiosk, printed exhibit guides, an educational information desk, teacher development workshops, open-house events for teachers and families, and a ten-minute video.
- Sponsor a dialogue in the science museum community on how to support science education reform through exhibits, including a symposium for museum professionals and educators, a presentation of our findings at the annual meeting of the Association of Science-Technology Centers (see "Personal Perspectives," beginning on page 46), and a final report on the project (this publication).

The Framework project—a thematic, reform-minded, deductive approach to teaching and learning—was new territory for the Exploratorium, which has traditionally focused on an experiential, inductive, bottom-up approach. This disparity raised several key questions:

- Was it possible to synthesize the two approaches?
- Would the necessary changes affect the quality of the Exploratorium's public environment?
- How would our relationships change with our most fundamental audiences: teachers, school-age children, and the visiting public?

Ideas for the project had been bubbling around the Exploratorium since the late 1980s. Senior Scientist Thomas Humphrey originally conceived the project as a general exhibit-development undertaking, one that would reconceptualize old exhibits, build new ones, and organize them in different arrangements using themes from the California Science Framework. He was interested in testing how effective thematic abstractions could be in an informal educational setting.

Executive Associate Director Rob Semper and evaluator Mark St. John envisioned the project as an opportunity to both support California science teachers through theme-based exhibits and address concerns about the value of informal science education. The Framework project, they asserted, could offer a model to demonstrate that exhibition development can make a direct contribution to formal educational infrastructure. Not only could the Exploratorium improve internal exhibits, but it could also disseminate information on science education reform efforts to parents, teachers, and the general public.

Science Education Reform and the Science Framework for California Public Schools

Since the late 1980s, science education reformers have promoted a thematic approach to science teaching. On the national level, the American Association for the Advancement of Science (AAAS), through its Project 2061, published *Science for All Americans*, a 1989 document outlining six broad themes that pervade the sciences: Systems, Models, Constancy, Evolution, Patterns of Change, and Scale. On the state level, the 1990 California Science Framework endorsed and extended the thematic approach for California students. The Framework themes—Energy, Evolution, Patterns of Change, Scale and Structure, Systems and Interactions, and Stability—provided perspectives for looking at links among the sciences.

The National Science Foundation accepted our "Facilitating the Framework" proposal just as Kathleen McLean joined the Exploratorium as Director of the Center for Public Exhibition, the area of the museum responsible for managing the project. Her expectations came from her experience developing thematic exhibitions: visitors would recognize comprehensible themes; staff would experiment with and be explicit about their exhibit development processes; and the project would revitalize the public learning environment.

Dennis Bartels, Director of the Center for Teaching and Learning, joined the staff after the project had been in place for one year. His expectations were shaped by seven years of direct experience with state curriculum frameworks and systemic reform in both California and South Carolina. Although skeptical that an exhibition-based project could have a deep and lasting impact on classroom instruction, he asserted that direct teacher involvement in the exhibit-development process was key to the project's success. He thought that the Exploratorium could discover new ways to develop and support teacher leadership by working directly with the museum's enthusiastic Teacher Institute alumni.

What began as a simple exhibit-development project turned into a major evaluation of what informal science education institutions may or may not be able to do well, and what services specific audiences appreciate and expect. When we embarked on the Framework project, little did we realize how far afield it would take us, and how much we would learn about our audiences, our exhibits, and ourselves.

This publication offers an overview of the Framework project and discusses our assumptions, challenges, questions, and diverse perspectives. We hope it will help expand the dialogue about science education reform and how informal science museums and science centers can play an appropriate and productive role.

—Dennis Bartels, Thomas Humphrey, and Kathleen McLean
Exploratorium, Fall 1999

A Note from the Director

Over the course of its life, an institution undergoes growth and change in order to continue to meet the needs of its audience. Some changes are the result of a gradual evolution of policies, philosophies, and goals. Others are the result of a focused, deliberate effort to work in cooperation with other institutions and organizations.

In 1994, the Exploratorium was offered the opportunity to experiment with this sort of focused rethinking. Through a generous grant from the National Science Foundation, we were able to explore the role of an informal science museum in supporting and facilitating changes that have occurred in the way science is taught in schools.

In a series of four large exhibitions and exhibit collections, we used the thematic model presented in the *Science Framework for California Public Schools* to offer an exciting new perspective on the sciences to teachers, students, and the general public.

As you will read in the essays in this volume, the project had far-reaching, long-lasting effects for the Exploratorium, its exhibit collection, its staff, and its visitors. I hope that you will benefit from the results of our explorations.

Goéry Delacôte
Executive Director

An Overview

THE FOUR THEMATIC EXHIBIT EXPERIMENTS

A Question of Size

February 13, 1996–January 4, 1997

A Question of Size was an exhibit collection—a group of individually designed exhibits—focused on the Framework theme of Scale and Structure. We partially "corralled" the collection and created distinctive exhibit graphics for consistency, assuming visitors would recognize connections among adjacent exhibits. We embedded the theme in many exhibits so that visitors would have to search for it beyond their primary interactions. When we evaluated the visitor experience, we found that most people realized the collection was somehow about size, but they missed the fundamental ideas about scaling.

- ▸ **1** Blue-screen technology used in the exhibit "In the Land of the Ants" let you superimpose your world on that of an ant.
- ▸ **2** At "Double the Doggie," building a scale version of a small plastic-block dog resulted in a model twice as large in all dimensions, requiring a surprising number of blocks.
- ▸ **3,5** Family Night offered a variety of size-and-scale-activities.
- ▸ **4** "Big Chair," built by doubling all the dimensions of a regular chair, ended up being eight times as heavy.
- ▸ **6** Foam models at "Trees" showed the relationship between size and flexibility: doubling the dimensions made a big, floppy tree.

Cycles: Nature Repeats Itself

September 17, 1996–April 30, 1997

Cycles was an exhibit collection focused on the Framework theme of Patterns of Change. Because of visitors' difficulty with the theme in *A Question of Size*, we gave the *Cycles* collection a much simpler focus. We also redesigned the exhibits to be more visually similar. Huge wall-sized graphics accompanying the collection "shouted" the theme to visitors. We found that most visitors could articulate the theme of Cycles, but many staff felt that the exhibit collection was too one-dimensional and simplistic.

- **1** At "Bike Cycles," if you pushed the buttons in the right order, and at the right time, a robotic cyclist would pedal a bike.
- **2** Hands-on activities proved popular at Cycles Family Night.
- **3** At "Chicken Life Cycle," live chicken embryos were shown at different stages of development.
- **4** In the multimedia piece "Cycles Stories," twelve people from various walks of life talked about how they were affected by cycles.
- **5** A spinning ball in "Gravity Well" modeled orbital cycles.
- **6** Like their counterparts in nature, three different-sized geysers in the "Geysers" exhibit erupted in regular cycles.

1
Boundaries
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and keep
other things out
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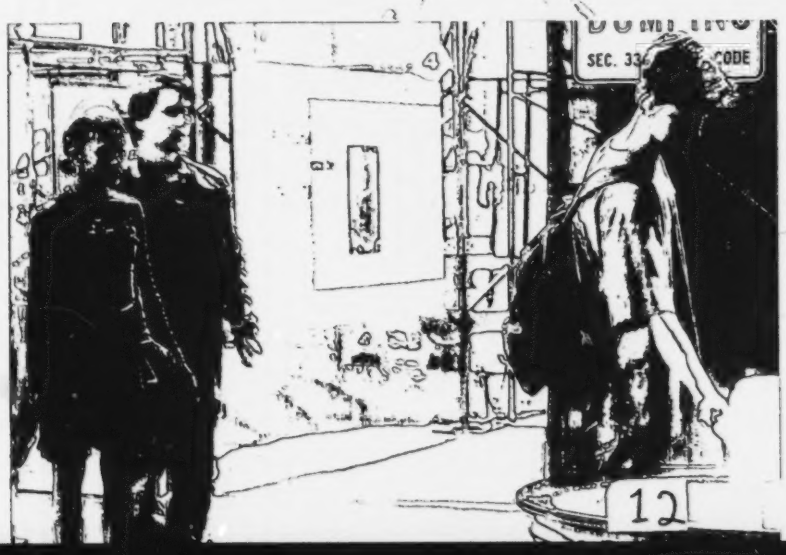
Boundaries: It All Happens at the Edge

February 22, 1997–May 4, 1997

Boundaries was a true exhibition, a holistically designed environment focused on the staff-conceived theme of Boundaries. We designed walls, furniture, graphics, and all other exhibit elements to support and embody the theme. We found that the majority of visitors could articulate the exhibition theme, and they experienced it as more philosophical, conceptual, and theme-based than other exhibitions.

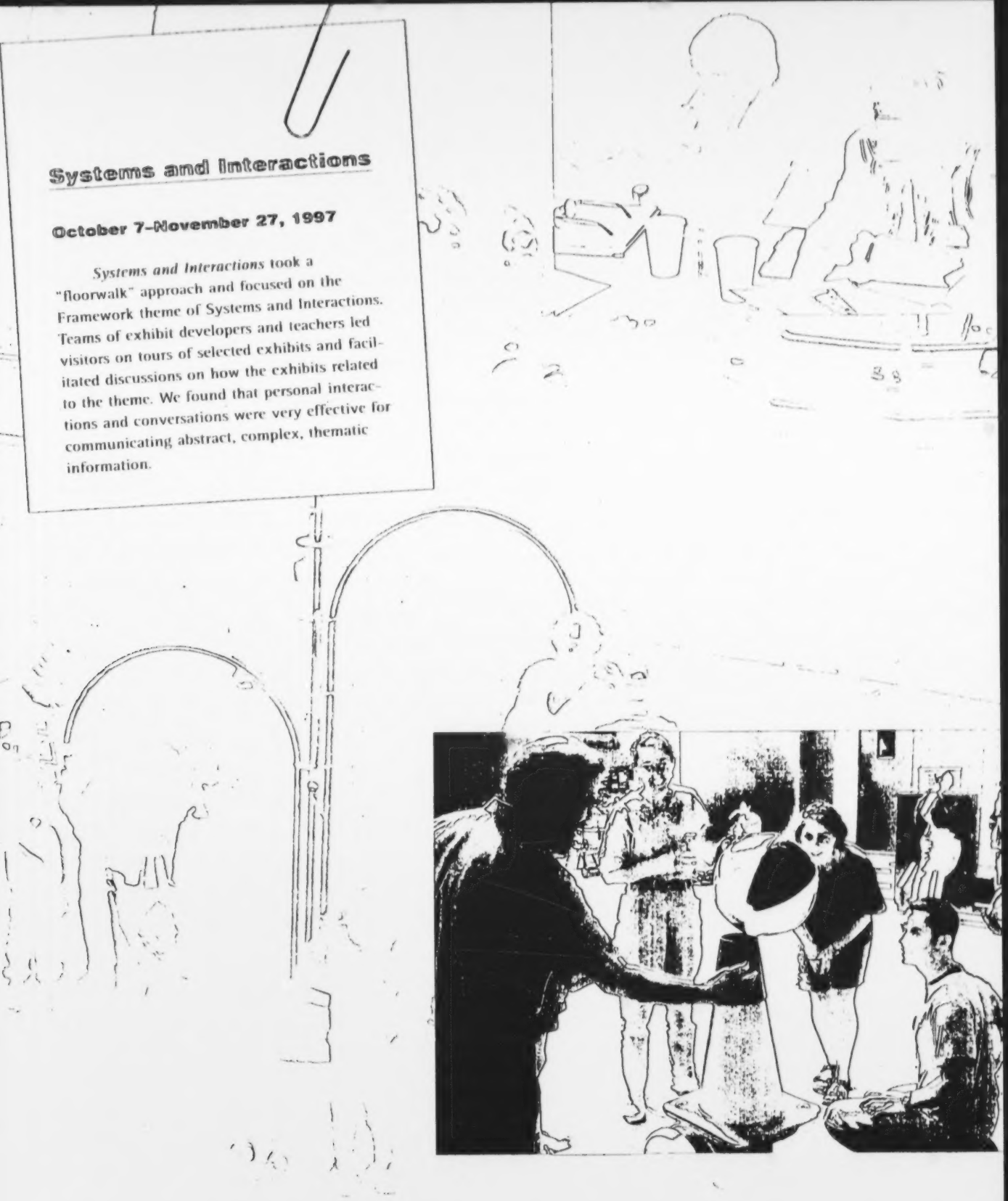
- ▷ **1** Visitors could put a hand on the water's surface and look into a mirror to see an underwater boundary.
- ▷ **2** Brief, thought-provoking graphics immersed the visitor in the Boundaries experience.
- ▷ **3,6** Staff members helped visitors explore at the "Boundaries Bar."
- ▷ **4** A misting fountain let visitors explore the boundary between air and water.
- ▷ **5** A tongue-in-cheek fashion show of protective clothing revealed the boundaries we place between ourselves and our environment.



Systems and Interactions

October 7–November 27, 1997

Systems and Interactions took a "floorwalk" approach and focused on the Framework theme of Systems and Interactions. Teams of exhibit developers and teachers led visitors on tours of selected exhibits and facilitated discussions on how the exhibits related to the theme. We found that personal interactions and conversations were very effective for communicating abstract, complex, thematic information.



THEMES

"We'd never worried on this level about how a group of exhibits was going to work together, what they would say collectively. We'd done exhibitions based on an umbrella idea, but each individual exhibit was left to bubble up with it's own unique thing. We weren't trying to teach something this specific and focused."

—Jim Meador
Exhibit Developer

"The tricky thing about the Framework is that the themes are not just any themes connected together. They are meant to be themes that have a fundamental profundity in science."

--Thomas Humphrey
Senior Scientist

When the Exploratorium opened in 1969, most people considered science education a formal process of lectures and didactic learning that took place in classrooms. But Exploratorium founder Frank Oppenheimer and other education reformers believed that there were more effective ways for people to learn about the world around them. They were experimenting with new methods of teaching and learning that focused on learner-centered pedagogies—a radical idea at the time.

The Exploratorium was designed as an experiment, offering visitors the opportunity to make discoveries for themselves, and then recognize relationships between seemingly-unconnected phenomena. For instance, visitors might see a rainbow in the Color section of the museum, then listen to a high-pitched noise in the Sound section, and discover that these two quite different phenomena were linked together by the concept of waves. They could experience for themselves that science is not just an assortment of interesting phenomena, but also a conceptual framework for thinking about them.

When we wrote our NSF grant "Facilitating the Framework," the California Science Framework was only a few years' old (see Sidebar, page 2). Many classroom teachers had begun experimenting with thematic teaching but weren't clear on how to integrate it into their existing curricula. In 1993, we decided that we would put together a series of exhibitions based on the themes in the Framework. "Facilitating the Framework" envisioned a program that would model thematic teaching and provide support for local teachers who were using themes in the classroom.

As we began planning, one of the first problems we ran into was finding an answer to the deceptively simple question, What is a theme?

Exploratorium staff assumed that several of their previous exhibition efforts, including *Memory* and *Navigation*, were thematically based because they linked a variety of disciplines and conceptual approaches. Many elementary school teachers said they had previously organized their classes around themes such as "Animals" to link science, math, social studies, and literature. Middle school teachers said they had used themes such as "Oceans" to link the life, earth, and physical sciences.

But according to the California Science Framework, memory, navigation, animals, and oceans are topics, not themes. Topics represent palpable and observable phenomena. The writers of the Framework defined themes as the "big ideas of science," that should permeate science curricula and aid learners in making conceptual connections. Themes are generated by abstracting from what is measured and observed in the world.

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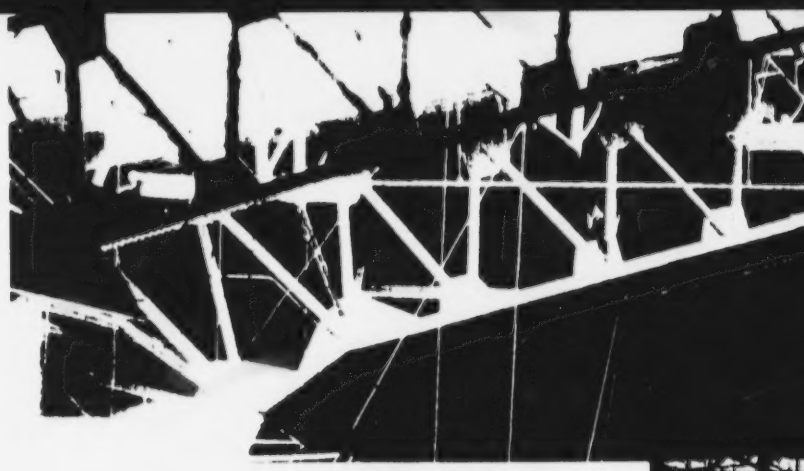
"We conceive of most of our exhibit pieces as props to link a pedagogical chain; frequently the links are common to several different chains."

—Frank Oppenheimer
Exploratorium Founder



The Framework document specifically describes six themes:

- Energy
- Evolution
- Systems and Interactions
- Stability
- Patterns of Change
- Scale and Structure

According to the Framework, each of these themes can be used as a filter, or lens, with which to examine the data and evidence of science.

Over the course of the Framework project, clarifying the definition of a theme took us quite a bit of time. Before we could even begin to approach the more concrete (but equally difficult) aspects of planning an exhibition, we spent hours trying to develop a shared understanding of a theme. This chapter discusses how we incorporated themes into the four Framework exhibit experiments, and how our visitors interpreted them.

A Question of Size

The first "big idea" we decided to tackle was Scale and Structure. We decided that one way to look at this (and other) themes was to ask questions. In the *California Science Teachers Journal* (Spring 1992), educator Douglas Martin said:

"A series of what I call 'thematic questions' bring out the essence of the themes in a simple and understandable way. I recommend that you weave these questions into your teaching as often as you are able. . . . Using these questions frequently . . . will get you started on thematic science teaching."

We used Martin's approach as we looked at animals, structures, and other objects and asked ourselves thematic questions:

- What factors limit the size of this thing?
- How is the size of this thing related to what it does?
- How would increasing or decreasing its size (scaling) affect its behavior?

Based on these questions and our own answers, we developed *A Question of Size*—a collection of exhibits that, we thought, demonstrated how profoundly scale affected structure and function.

In exit interviews, we asked visitors how they thought all the exhibits were connected. While most of the respondents recognized that the exhibits were about size, only a few could elaborate that they also involved scaling. The rest either didn't mention scaling at all, or touched on areas that were peripheral to the intended theme. "Different creatures are living, growing, working, and building on all different scales," was how one visitor explained it.

After *A Question of Size*, we regrouped. Part of the problem, we thought, was that scaling was not only a fairly high-level abstraction, but also a mathematical concept that made the thematic connection even more difficult for people to grasp. So we chose what we thought was a more accessible theme to try next.

Cycles: Nature Repeats Itself

For our second exhibit experiment, we picked the Framework theme of Patterns of Change, but then we decided it was much too broad to cover in an

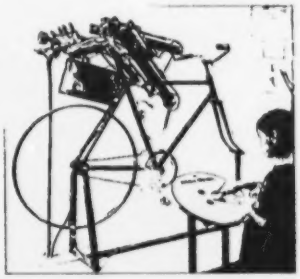
A collection of theme-based exhibits can give visitors a well-rounded view of interrelated phenomena.

"The Framework said, 'Thou shalt not teach this as a topic. Thou shalt weave it in gradually throughout thy curriculum.' But most people are only here for one visit, so the only way to have any kind of coherence is to pull exhibits together in one area, with a big sign over them that says CYCLES, or SIZE. But then the whole thing becomes a topic."

—Sue Allen
Project Evaluator

exhibit collection. Because the Framework subdivided this theme into Trends, Cycles, and Irregular Changes, we opted to focus on Cycles as the pattern of change that seemed most demonstrable and the most closely related to our existing exhibits.

Once again, we spent a great deal of time discussing just what the theme was before any new exhibit development began. We wanted to gather exhibits from as many different sections of the museum as possible and put them together so that their connections were thematic rather than phenomenological. This method of organization was an experiment for us. One staff member summed it up this way:



"The museum has always seemed to me a little bit like a hardware store. If you want a drill, you go to the Tools department. If you want some nails, you go to the Fasteners department. But in this project, it's different. It's like, now we've got the Pointy Things department, and there are electric drills, and nails, and awls, and fence posts, and maybe even pencils in it. It's interesting, but a little confusing."

After the exhibition, evaluation showed that approximately half the visitors understood the *Cycles* theme that connected exhibits as disparate as a chicken embryo and a recirculating geyser. But visitors seemed to find the individual exhibits more compelling than the theme. The staff felt that we had responded to the somewhat disappointing evaluation results of *Size* by selecting a much simpler theme and then oversimplifying its presentation. In order to "get the message across," some people felt that we had created an exhibit collection that was too superficial.

Boundaries: It All Happens at the Edge

Again we regrouped. The California Science Framework cautioned against taking too literally "the limited number of themes that are suggested in this Framework. Other formulations are possible. Diversity, Hierarchy, Matter, Motion, and Conservation are examples of other themes around which curricula may be organized, and there are certainly many more." We decided that if we created our own theme—one that came from the interests of staff—we might be more effective in communicating that theme to others.

Our first brainstorming session left us with a list of more than a hundred possible themes. In subsequent meetings, staff members and teacher advisors filtered, grouped, and condensed the list into one solid "big idea"—Boundaries. And it clicked. It suddenly seemed that everywhere we looked, there was a boundary. The theme connected to every area of science we considered.

Over a period of months, we struggled to define our communication goals for the exhibition, looking

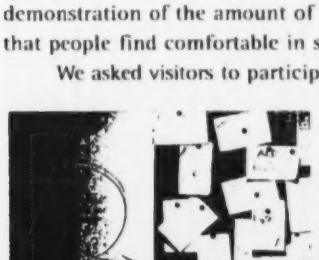
A collection of theme-based exhibits will be perceived by visitors on an experience-by-experience basis.

for a way to express the theme without oversimplifying it or losing any of its fascinating interconnectivity. We finally extracted three aspects of boundaries that we hoped visitors might comprehend:

- Boundaries separate things and create identity; without boundaries, life would be impossible.
- All boundaries are semipermeable membranes through which some things pass.
- Interesting things happen at boundaries, borders, and edges.

In its final form, the *Boundaries* exhibition connected such diverse exhibits as a tank of anableps (fish with divided eyes that can see both underwater and above water), a two-way mirror room, and a demonstration of the amount of "personal space" that people find comfortable in social interactions.

We asked visitors to participate, as well, creating areas where they could write their observations about boundaries on index cards. Their comments ranged from "underwear is a good boundary," to "some boundaries are easy to cross, like the peels of tasty fruit," to "it is an expanding universe—where's the boundary in it?"



Visitors described their experiences in the exhibition as interesting and thought-provoking, focused on social and psychological boundaries, and philosophical in nature. They also said the exhibition raised their awareness of boundaries in the world. The exhibition's physical phenomena provoked curiosity, but many visitors were still unable to use the phenomena to recognize the defining ideas of boundaries.

Systems and Interactions

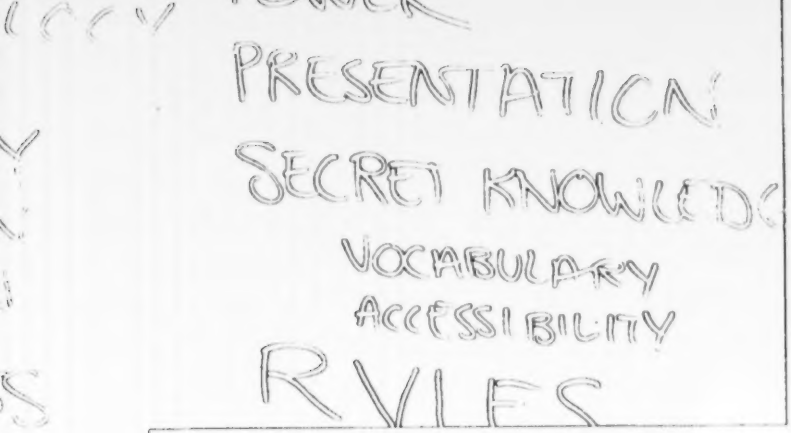
After *Boundaries*, we returned to the themes identified in the Framework, this time choosing to work on *Systems and Interactions*. At this point, we were beginning to focus on how the Framework promotes a gradual and consistent integration of themes, not singled out as units of instruction, like chapter headings. We agreed that, despite our best intentions, theme-based collections that gathered exhibits all together in one area really did fall into the "chapter heading" model. We had also learned that visitors' understanding of the previous three themes was greatest when we provided personal interactions and demonstrations.

So instead of an exhibition, we created a series of "floorwalks," mediated minitours led by an exhibit developer and a teacher. Created for teachers, these floorwalks modeled thematic, hands-on, inquiry-based teaching. The two leaders worked as a team to orchestrate an inquiry experience for visiting teachers, exploring a diverse group of existing exhibits and a systems perspective for thinking about each.

In choosing exhibits for these floorwalks, we first recognized that every exhibit could be considered a system with interacting parts—and so a possible candidate for inclusion. However, it became clear that some exhibits were more suited than others to the kinds of inquiry strategies we wanted to model. In the end, we used two criteria to choose exhibits:

- 1. Visitors should be able to readily manipulate the parts and observe the effects on the whole exhibit.

The themes suggested in the Framework are the ones teachers need to know about.



> "The most important aspect of the ambiance of the Exploratorium may stem from the fact that visitors are never subjected to judgmental discomfort. They do not feel compelled to decide whether they are supposed to learn something from an exhibit, or merely enjoy themselves."
>
> —Frank Oppenheimer
> Exploratorium Founder

(This criterion led us to exclude such obvious candidates as aquaria and terraria, because visitors couldn't easily change the parts of an ecosystem.)

▶ 2. Visitors should be able to easily understand the exhibit—at least at a basic level—so the guides could spend the limited time exploring the systems aspect of the exhibit rather than explaining the content.

Of the four experiments, the floorwalks were the most successful in communicating what a theme was, how it connected things, and how it could be used to teach science.

Themes: An Open Question

When we started our floorwalk program in the fall of 1997, the number of teachers who were still attempting to incorporate Framework themes in their classrooms was dwindling. One teacher in our advisory group said that although her district had adopted theme-based teaching, many teachers had already dropped efforts to implement it. Others said they were actually teaching less science than before because themes added another level of complexity to an already difficult job.

For teachers in schools, like exhibit developers at the Exploratorium, when and how to incorporate themes remain open questions. Most elementary school teachers, who have the same students over the course of a year, are in an ideal situation for gradually weaving thematic connections through a wide variety of subjects. But many, if not most, simply don't have enough science background to make big, abstract, multidisciplinary connections. High school science teachers—while generally offering more breadth and depth of knowledge of their subjects than elementary school teachers—are also more specialized. A biology teacher, for example, has less opportunity to make "big connections" to physics, chemistry, or mathematics in his or her classroom.

Clearly, the distinction between themes and topics is a confusing one, and themes add an extra level of abstraction that most teachers—and most developers of phenomena-based exhibits—are unable or unwilling to take on. At the same time, there are some teachers and exhibit developers who embrace the thematic approach and are comfortable working within this more abstract realm. When people do make connections and grasp the "big ideas" of science, the experience can be quite profound.

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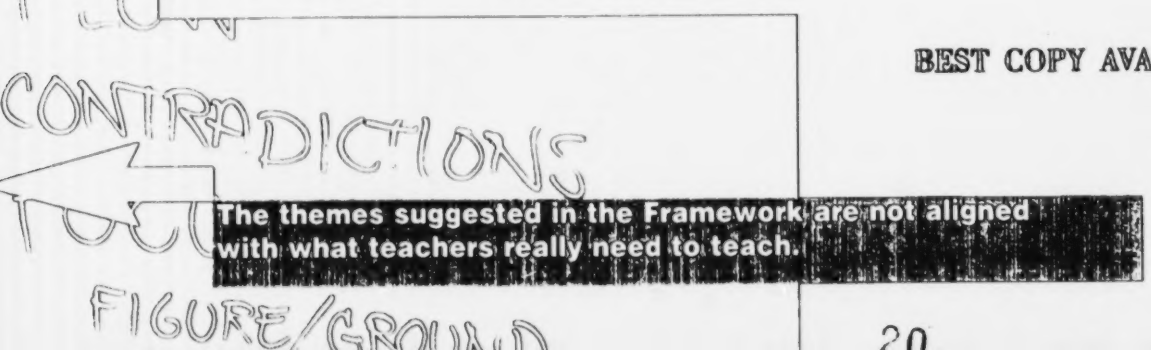
CONTRADICTIONS
The themes suggested in the Framework are not aligned with what teachers really need to teach.
FIGURE/GROUND

CREATING AN ENVIRONMENT

21

"An open plan works well in many science centers where informal wandering among exhibits is encouraged. But in a . . . thematic exhibition, the open plan is problematic."

—Kathleen McLean
Director, Center for Public Exhibition

Exploratorium founder Frank Oppenheimer once wrote that the museum was "a place for sightseeing, a woods of natural phenomena through which to wander." Some have also compared walking through the Exploratorium to strolling from one neighborhood to another: The scenery changes, but there are few definite borders.

From the museum's opening day, its vast floor has had few interior walls dividing exhibit clusters. In some places, area signs indicated exhibit groupings of like phenomena—light, color, sound—but there has never been an "Electricity Room" or "Life Sciences Pavilion." The expertise of Exploratorium exhibit developers has traditionally been in creating individual exhibits that demonstrate related phenomena, and then in grouping those exhibits into areas such as "Light" and "Patterns." The Framework shows were a departure from that model because the connections were thematic, not phenomenological. The layout of the museum's exhibits gives the impression of a casual, unstructured space, supporting the Exploratorium's philosophy of a visitor-driven experience.

One of the Exploratorium's strongest philosophical tenets has always been to encourage visitors to explore freely and follow their curiosity. This approach permits people to make their own connections and discoveries about the world around them. For the Framework project, however, we added a new goal: We wanted visitors to see how disparate natural phenomena were connected by big, overarching ideas like Size and Scale, Cycles, Boundaries, and Systems and Interactions. This goal brought with it issues of focus, definition, and context.

A Question of Size

The First Framework "show" was *A Question of Size*, based on the theme of Size and Scale. We structured this collection by grouping exhibits into thematic clusters and installing them in an area along one wall of the museum. After months of discussion, we decided to define the space and emphasize the unique, thematic connection of the exhibit grouping by running giant rulers—about a foot wide, at waist height—along the two open sides of the area. The rulers were not walls, but many staff felt uncomfortable with even this division of space.

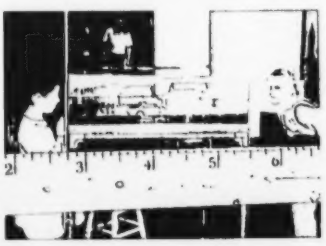

Exhibit developers soon discovered that the rulers had little, if any, effect on visitors' ability to distinguish the collection from other exhibits on the floor. In fact, visitors picked up distracting and unintentional cues from the surrounding environment, influencing their experiences with the collection.

"Exploratorium exhibits are divided into 13 sections. There are no walls dividing the sections. . . . We feel that the lack of walls encourages a kind of free-ranging exploration and helps people realize that the sections are somewhat arbitrary."

—Frank Oppenheimer
Exploratorium Founder

For example, one side of the exhibition abutted a large, permanent Ames room, which creates the illusion that people are bigger (or smaller) than they actually are. The Ames room is, indeed, about scaling (people seem to grow bigger or smaller as they walk around inside a distorted room), but it's about perceptual scaling—things appearing to be different sizes. We were afraid that visitors, already somewhat unclear about physical scaling, would become even more confused by the second concept of perceptual scaling.

This was a real concern: As it turned out, the outside of the Ames room, which was decorated with a painted illusion of two large cows in inaccurate perspective, added to visitor confusion. Twelve percent of visitors said they thought the theme was "perception," and another eight percent thought it was "animals." Several *Size* exhibits did contain animals—ants, mice, giant hissing cockroaches, vinegar eels—to demonstrate scaling in nature. Juxtaposing these animals with the enormous images of two cows looming over the area was enough to create a stronger connecting theme than all the carefully crafted exhibit labels explaining size and scale.

Although we developed a different style of graphics specifically for *Size*, and even defined the space with the rulers, *Size* was still fundamentally a collection of exhibits that aspired to be a unified exhibition.

Cycles: Nature Repeats Itself

Our second effort was more cohesive but still didn't break through the "collection of exhibits" barrier. While positioned in a central area in the front of the museum, *Cycles* had no walls or fences. To define the area, we experimented with big environmental graphics—wall-sized images and blocks of text. Although we had occasionally employed this type of graphic before, it was by and large a departure from the Exploratorium's usual style.

Because many exhibits in the museum already involved one kind of cycle or another, developers assumed it would be a simple task to pull them out of their phenomenological sections, rework the graphics to focus on the cyclic component of each,

The Exploratorium's open exhibit floor lets visitors discover how exhibits are related to one another.

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and put them all together in the *Cycles* area. This assumption was in line with how we generally view our exhibit collections: We see them as teaching props that demonstrate a variety of phenomenological topics. For example, an exhibit on optics may also be used to model aspects of color perception, light, vision, or wavelengths of the visible spectrum. In this way, the exhibits serve as elements that can be grouped and regrouped to create collections that reveal a variety of connections.

For the Framework project, however, we discovered that what had been a plus in a phenomenological grouping became a minus in a thematic one. The open-ended aspects of the *Size* exhibits, for instance, distracted visitors from the theme, rather than reinforcing it.

When we planned *Cycles*, we grappled with this tension between broad and narrow focus, and between phenomenological and thematic groupings. Some staff felt that if our goal was to have visitors discover or comprehend one overarching theme, it would be better not to offer them multiple connections.

In exhibit development meetings, for example, there were arguments over how to best use exhibits such as "Heat Pump," a model of a working refrigerator. At this exhibit, visitors turn a crank that runs a compressor, then put their hands on two coils; one coil gets hot and the other gets cold. A refrigerant cycles through the inside of the pump and changes from liquid to vapor to liquid. This cycle is an essential part of the mechanism, but it's not the first thing

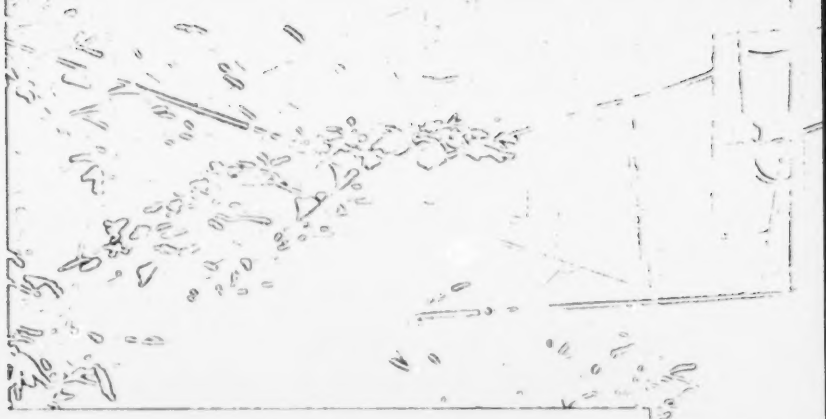
visitors notice. It's embedded into a deeper layer of the experience, requiring much more time and attention. Some developers wanted to retain the exhibit's complexity, demonstrating the multiple connections between heat, cycles, systems, and mechanics. Others wanted to emphasize only the cyclical elements, so that the thematic connection would be unmistakable. Considered an appropriate narrowing of focus by some, this view was seen as "dumbing it down" by others.

In the end, very few exhibits were radically changed. But the threat of that change caused heated debates and forced some staff involved to reexamine their beliefs about the function of exhibits on the floor.

Boundaries: It All Happens at the Edge

Hoping to design an exhibit collection that was more understandable than *Size* and more compelling than *Cycles*, we designed *Boundaries*, an environment separated from the rest of the public space by very obvious, though "permeable," scaffolding-type walls. A clearly defined entrance made it impossible to wander off the floor and into this thematic exhibition without noticing. *Boundaries* made the leap from being an exhibit collection to being a true exhibition.

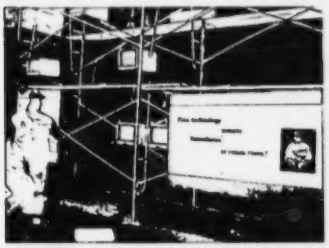
The Exploratorium's open exhibit floor is confusing for visitors, who may have no way of knowing how one exhibit relates to another.



"Nature doesn't put all of this stuff together in a little room called 'Cycles.' It's scattered all over the place. It's wherever you are, and you find it in surprising places."

—*Mary Miller*
Science Writer

The graphics for the *Boundaries* exhibition were a departure from anything the Exploratorium had ever used before. They were evocative of boundaries, with minimal text and without the "What's Going On?" sections on scientific background. Exhibits and installations, conceived specifically for the exhibition, were not titled. This had the effect of tying them more closely to the exhibition theme, without calling attention to their individuality. Instead, the focus was on the visitor's experience of various kinds of physical and social boundaries, rather than on more phenomena-based content.



Center for Public Exhibition Director Kathleen McLean commented:

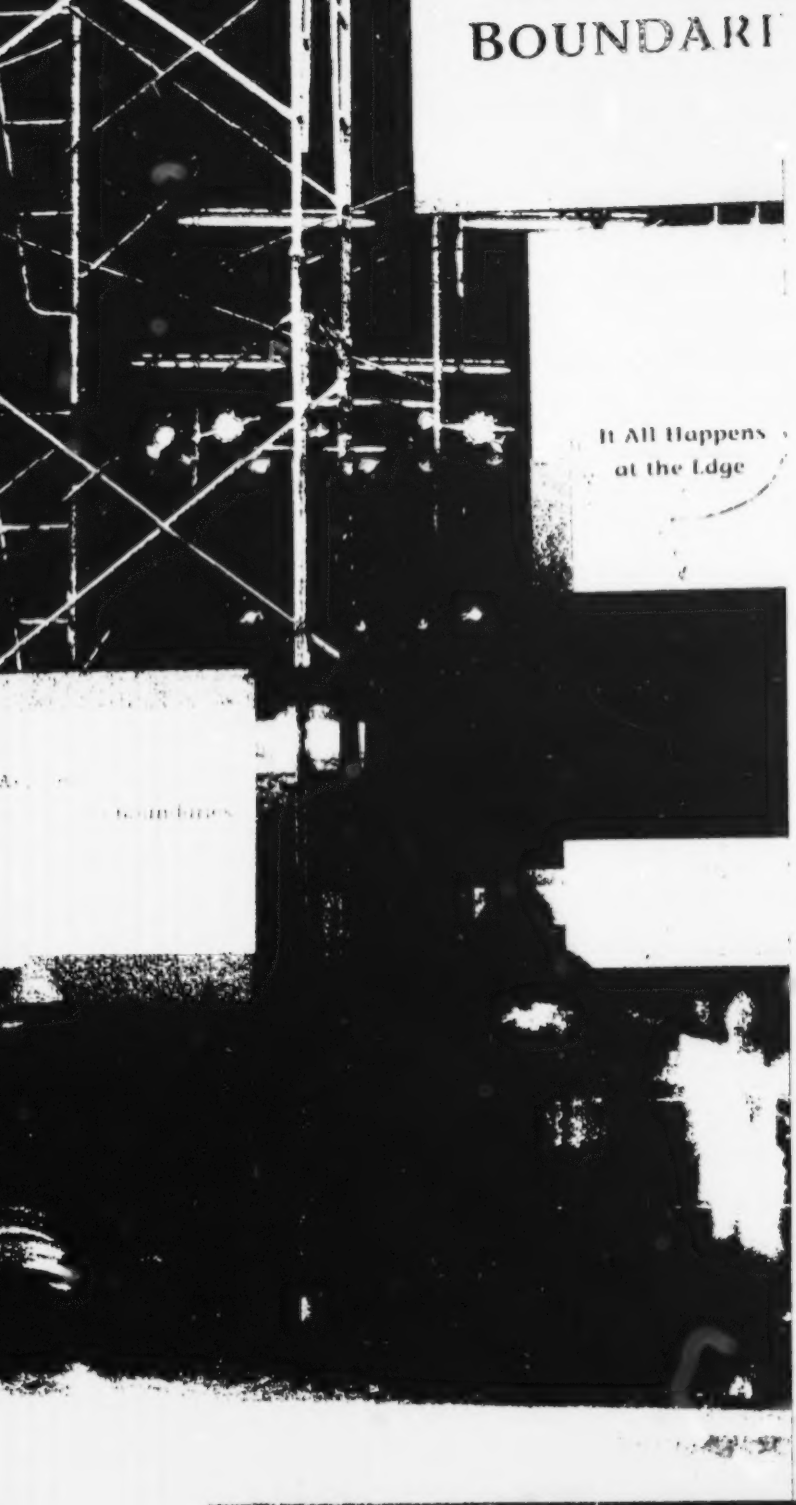
"The visitor's experience is the culmination of the environment, the quality of light, the look and feel and content of the exhibits, and all that we design and plan and control. And all these elements must in some way embody the theme."

Based primarily on its environmental and contextual approach, the exhibition received the 10th Annual Excellence in Exhibition Award at the 1998 meeting of the American Association of Museums.

Systems and Interactions

When we decided to offer exhibit-based floorwalks for our fourth theme presentation, *Systems and Interactions*, we had essentially come full circle. Over the years, our teaching programs have thrived on the approach of offering educators intensive, well-planned mediation focused on museum exhibits. This time, we did essentially the same thing, taking advantage of staff expertise and the most effective environment we have—the entire museum floor.

Exhibits should be grouped into separate thematic areas.



"In a classroom, you have the kids for a year. And you can weave something in and through a lot of lessons, refer back to it. But in an exhibition, the kids are there for maybe ten to fifteen minutes. It's a very different environment."

—Jan Davidson
Project Manager

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Exhibits should remain in their phenomenological areas, with thematic connections drawn among them.

AUDIENCE

"We are careful not to impose any behavior patterns or learning strategies on our visitors. . . . In the end, all manner of people discover how to use this place. We observe that they use it in many different ways and for a great variety of purposes."

—Frank Oppenheimer
Exploratorium Founder

"Who are the experts? The visitors are the experts. But only up to a point. They are experts in terms of what they want, what they understand. But they're not experts in the problems of exhibit development. You don't ask them what color to paint something."

—Shawn Lani
Exhibit Developer

When the Exploratorium first opened in 1969, its audience was whoever walked in the door: park visitors, scientists, friends of staff, neighbors from the surrounding Marina district. No attempt was made to target a specific audience for the museum or its exhibits.

This holistic attitude about audience was intentional, based on founder Frank Oppenheimer's philosophy that Exploratorium exhibits should work on a variety of levels and appeal to a variety of people. In a 1986 article entitled "Everyone Is You . . . or Me," he said:

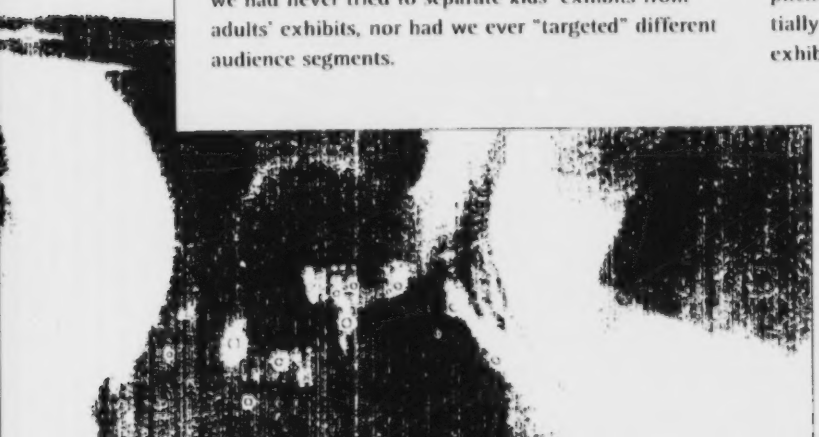
"There are two things misleading about the statement, 'You have to define who your audience is.' In the first place, it is possible to make many, if not most, of the exhibits so that they can each individually be appreciated and enjoyed on a variety of levels. Secondly, it is ridiculous to think that every visitor should be able to appreciate or enjoy every exhibit in the museum."

Over the years, the museum had done periodic demographic studies to find out who was coming through the door and determine whether we were serving the diverse population of the Bay Area. But we had never tried to separate kids' exhibits from adults' exhibits, nor had we ever "targeted" different audience segments.

Going into the Framework project, we assumed that, as always, our audience was the general public, but with a greater proportion of teachers, education administrators, parents, and students. Although elementary and high school teachers have very different curriculum needs, we assumed that our exhibits would provide multiple levels of information and experiences that any teacher could use in his or her own classroom. From the beginning, however, the abstract nature of the thematic approach required us to challenge these assumptions, reevaluate the needs of different audiences, and identify the specific audience we were really trying to reach.

A Question of Size

For *A Question of Size*, our first Framework project, one method for assessing audience needs was to involve teachers (a subset of our audience) in the planning stages, and incorporate their critiques of individual exhibits. For example, if teachers liked an exhibit, thought it was an acceptable model of the phenomena involved, but considered it only tangentially related to the theme, we either reworked the exhibit or cut it from the collection.

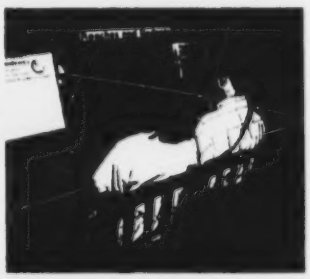


Another audience assessment method was systematic evaluation. Prototyping exhibits on the floor has always been at the heart of exhibit development at the Exploratorium. This process included talking to colleagues and visiting scientists about the exhibits and watching how people used them. Did the buttons work? Would they hold up under an onslaught of twelve-year-olds? Are people stopping to play with the exhibit, or are they taking one look and walking on by?

Before the Framework project, exhibit developers rarely talked to visitors. Instead, they watched, unobtrusively observing, and eavesdropped on conversations about the exhibits being tested. Then they reworked exhibits based on their own creative instincts and their assessments of what they had seen and heard.

When we began work on *A Question of Size*, we quickly realized that by only watching people use individual prototypes, we were learning little about whether visitors were getting the thematic message of the collection. Some staff members were suspicious of more formal evaluation, however, feeling that it interfered with the creative process of exhibit development. But Kathleen McLean, the new director of the Center for Public Exhibition (CPE), and Sue Allen, our in-house evaluator, persuaded us to experiment with systematic visitor interviews, and we began to ask people about their interpretations of *Size* exhibits.

The interviews were eye-opening for some staff. In the "Roaches and Rodents" exhibit, for example, we designed two side-by-side terraria with animals of about the same size. One contained very small mice; the other housed specimens of the world's largest cockroach species. We intended the exhibit to introduce scale and structure—two concepts that account for the maximum or minimum sizes of animals.



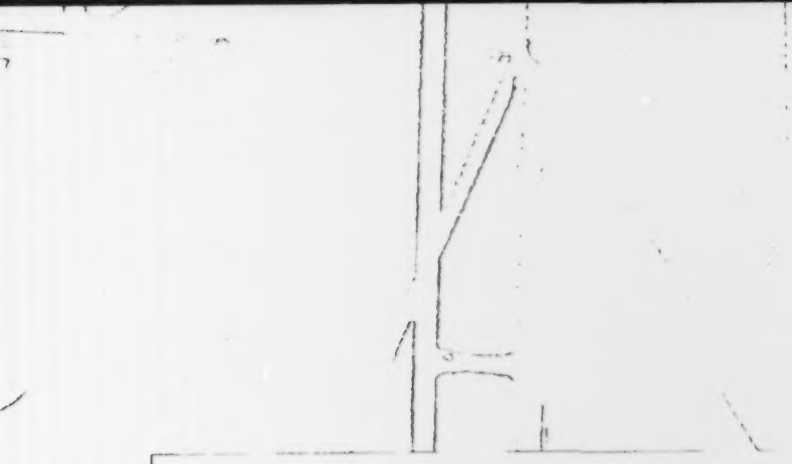
The exhibit proved to be quite popular. People spent extended periods of time watching the animals. But when we asked visitors why they thought the two animals were displayed together, they responded: "Both cockroaches and mice are problems, and they both make people uncomfortable"; or "These are both things that could be in your house."

If we'd been using the "unobtrusive observation" method, we would probably have concluded—from the amount of visitor time and interest—that the exhibit had been a success. But by talking with visitors about this and other exhibits, we discovered that we had underestimated the subtlety and complexity of the thematic ideas we were trying to demonstrate.

We had begun these visitor interviews midway through the development of the *Size* collection, when Sue Allen joined the Exploratorium as our in-house evaluator. Sue commented:

"Our audience hadn't learned what we'd hoped about scaling, but at least we were learning about them. One clear lesson from Size *was that front-end evaluation was particularly important for a show with an abstract theme. Unfortunately, we hadn't done any*

Exhibits are props that can support a variety of school curricula:



systematic front-end evaluation for Size, *so we learned too late that our essential reasoning about scaling was too esoteric for many of our visitors. Worse, we discovered that many didn't discriminate among the concepts of length, area, and volume. If developers had known that before starting the process, we would have tried to find a less ambitious approach to this challenging theme."*

After this experience, front-end, formative, and summative evaluations became regular parts of our exhibit development process.

Summative evaluation for this collection, conducted by Inverness Research Associates, was enlightening but discouraging. While many teachers surveyed said that the exhibits were interesting, most indicated that they were not familiar with the California Science Framework and did not use thematic teaching in their classrooms. One teacher said:

"Our curriculum is not set up to teach thematically. . . . You're given so much to cover in one year. Unless you know in advance how to integrate concepts, it's just too difficult."

Teachers also interpreted "thematic teaching" to mean a variety of things, from team-teaching across different subject areas to organizing lessons around broad topics, such as "oceans" or "weather."

In terms of presenting a thematic idea for the general public, the exhibit collection had also missed its mark. When we asked visitors what they thought was the theme of the exhibit collection, most of the people surveyed said something relating to size. That was, in fact, the basis of the theme, but we had hoped that visitors would also understand the deeper aspects of the theme—scaling. When asked more specifically, "Was there a message about size?" only a small percentage of our visitors mentioned scaling.

"People come to the Exploratorium because we aren't replaying the same things and the same teaching methods that other people do. We should play on our strengths, rather than trying to adapt ourselves to somebody else's idea of how science education ought to be done."

—Mary Miller
Science Writer

Cycles: Nature Repeats Itself

In the second exhibit collection, we conducted a basic front-end evaluation very early in the development process. We learned that most visitors were familiar with the word "cycles" and could define it in a way that was compatible with what we'd been discussing—emphasizing repetition and a return to an original state or place. However, visitors struggled to give examples of cycles; the two most common were extremely literal—menstrual cycles and bicycles. Moreover, the evaluation showed that while most visitors knew what a cycle was, they did not feel surrounded by cycles, nor were they impressed with their significance.

Our Advisory Group, made up of Bay Area teachers, conducted informal surveys with their colleagues to find out what other teachers knew about cycles and how the theme might be relevant

Exhibits are social experiences for informal learning.

"The public wants a good experience. They want something stimulating and thought-provoking. And teachers also want that. But they want something that connects to their teaching, something they can take back to the classroom."

—Sue Allen
Program Evaluator

to their curricula. Armed with this information, the development team discussed what *Cycles* should attempt to communicate before we began any new exhibits. Rather than trying to convey complex abstractions that might confuse visitors (such as "the physical world depends on cycles to create order and stability"), we decided to focus on these two simple messages:

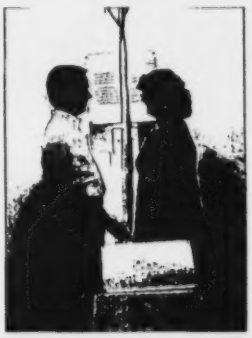
- Cycles are all around us, in both expected and unexpected places.
- Cycles dramatically affect our lives.

Summative evaluation showed that most visitors realized the exhibit collection was about cycles, and that cycles were ubiquitous, but this didn't seem to strike them as a profound idea. The evaluation indicated that visitors were more intrigued by the phenomena demonstrated in individual exhibits than by the idea of cycles as a connecting theme.

Boundaries: It All Happens at the Edge

The California Science Framework didn't specifically cite Boundaries as one of its themes, but front-end evaluation showed that the general public was interested in an exhibition about boundaries. When we asked people to give examples of boundaries, they came up with an impressive range of examples, from rivers and fences to laws and plate tectonics.

Rather than relying primarily on text to focus visitors on communication goals and present exhibit content, developers concentrated on providing an experiential environment that would embody the theme. We developed all exhibits based on their ability to provide boundary experiences: Can something pass through? Why? If not, why not?



Visitors created their own boundaries of "personal space" when they stood too close to a stranger, or walked around a lifelike mannequin holding a camera. They broke air/water boundaries with their hands, passed objects through sheets of soap film, and stood in a room where they could alternately see other visitors and be seen by them.

Even the perimeter exhibition walls, made of construction scaffolding, were intended to provide visitors with boundary cues. (In a sense, this was too effective; some visitors thought the wall was an impenetrable boundary with construction work going on inside—and they didn't come in.)

The boundary between creating and viewing an exhibit was blurred by an area where visitors could share their own thoughts about boundaries. One person wrote, "There is a boundary my wife has built between us, and I don't know why." Other comments ranged from "My dad can't chew tobacco after 7:00"

Playing with an exhibit can be a great experience, even if the exhibit doesn't do what the visitor expects.

"I don't think there is anything that distinguishes the natural curiosity of the teacher from the natural curiosity of a visitor."

—Dennis Bartels
Director, Center for Teaching and Learning

to "A boundary is set by your society, but reinforced by your mind."

Systems and Interactions

Based on visitor response to mediated experiences and demonstrations in *Cycles* and *Boundaries*, we decided to develop floorwalks as the method for conveying our fourth theme, Systems and Interactions. The guided floorwalks focused on existing exhibits to provide more individual attention for small groups of visitors. In order to facilitate visitor inquiry, the project evaluator and project manager prepared a training plan for each pair of guides—a teacher and an exhibit developer.

Systems and Interactions floorwalks were offered during the museum's open hours. Classroom teachers on field trips could sign up to take the half-hour floorwalks. No two tours were ever alike; the flow of the tour from exhibit to exhibit and the directions that it took at individual exhibits depended on the inquiries and interests of the audience participants.

Our teacher advisors suggested that we develop separate tours tailored to the needs of elementary, middle, and high school teachers. However, because of the random mix of field-trip teachers at the museum on any given morning, the floorwalks almost always included teachers from a wide range of grade levels. This mix turned out to be no problem; the inquiry-based format of the floorwalks allowed each person to approach the Systems and Interactions theme at his or her own level.

As an experiment, we gave floorwalks for the general public on two Saturday mornings. Except for the problem of parents being distracted by their small children who suddenly decided to take tours of their own design, visitors seemed to appreciate the public floorwalks.

Overall, the floorwalks were successful both in satisfying audiences (survey participants were positive about the experience) and modeling how hands-on exhibits can be used to teach thematically.

"Exhibitions run into trouble when the actual audience and the target audience aren't the same."

—Kathleen McLean
Director, Center for Public Exhibiton

Playing with an exhibit can be a great experience, as long as the exhibit doesn't frustrate the visitor by not working as expected.

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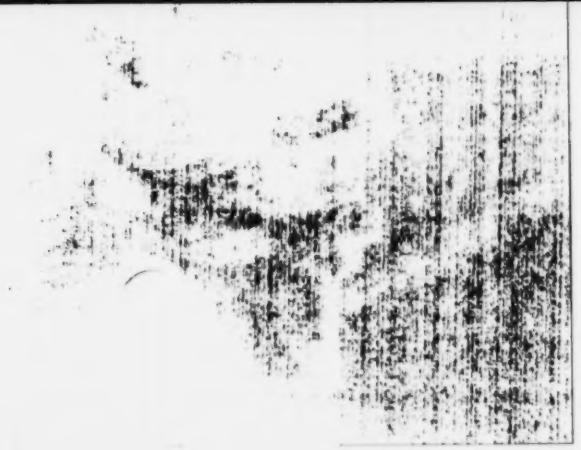
STAFF-VISITOR INTERACTIONS

"Let's say a teacher called me up and said, 'I'd like you to take my class through the museum and discuss symmetry with them.' Now, we don't have a Symmetry section. So I'd take them for a walk through the floor and weave a story. And the individual exhibits provide the primary experience, the hands-on wow! for each member of the class."

—Thomas Humphrey
Senior Scientist



"We always got the same reaction from Boardwalk participants: 'That exhibit was so much better! I got so much more out of this than I did before.'"

—Thomas Humphrey
Senior Scientist

The Exploratorium model for a visitor's experience has been one of self-discovery. Each individual's experience here is a personal, social process. We have avoided creating predetermined paths or offering "canned" tours. Visitors interact, tell each other stories, ask and answer each other's questions. People are free to wander according to their own curiosity, and to make their own connections.

At the Exploratorium, staff interact with visitors not as experts who can give the "right answer," but as mentors who may help with exhibits, conduct hands-on demonstrations, or give directions to the bathrooms or cafe. These interactions are primarily visitor-driven: the visitor has a specific agenda or a goal—whether it be learning about a particular thing or finding a specific location—which staff members help to facilitate.

In the Framework project, we searched for ways to provide visitors with the tools to discover for themselves the overarching ideas that our exhibit collections illustrated. We tried a variety of approaches and realized that we needed to increase the number of opportunities for visitors to interact with staff.

A Question of Size

In *A Question of Size*, we concentrated on graphics and signage to guide visitor experiences. But people can't ask a sign questions or tailor a sign's message to their wide-ranging interests, and many of the exhibits turned out to be more difficult for visitors to grasp than we had anticipated. When visitors could ask questions and explore an exhibit step-by-step, comprehension increased dramatically. As a result, some of our exhibits evolved into demonstrations conducted periodically by staff members over the course of a day.

Visitors' understanding was not the only reason to add staff participation to an exhibit. There were some practical, nuts-and-bolts concerns as well. Project Manager Jan Davidson recalls:

"In an exhibit that showed how scale affects weight, there was a little metal truck and another truck twice as big—eight times the volume. Pieces of Styrofoam were used as bridges that would hold the little truck, but not the big truck. The first hour we had it out on the floor, a small child came up and saw it as a karate opportunity, chopping through about half of our day's worth of Styrofoam™. We turned the exhibit into a staffed demo."

In *Size*, our experiments with adding staff interactions were limited to occasional demonstrations. For the most part, we left visitors alone to explore the exhibits, led by their own curiosity, as we'd usually done. Although visitors enjoyed the exhibits and knew they had something to do with size, few came away with an understanding of the underlying theme of scaling that we were trying to convey.

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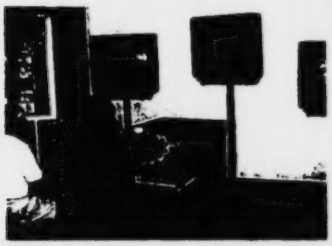
"I always totally rejected the idea of tours. I thought it was the opposite of what we were about. But it was clear after our walk that people were coming away saying things that suggested that they got the theme."

—Symposium Participant

Cycles: Nature Repeats Itself

Since getting across an abstract theme was proving to be a different challenge from presenting a natural phenomenon, we experimented a little more with narrative and a human focus to create a context for our second collection, *Cycles*. For example, we experimented with a video installation showing twelve people—from a rabbi to a car mechanic to a restaurant owner—talking about the cycles in their lives. Some exhibit developers felt that the videos were just "talking heads," and that the visitor was a passive viewer. Besides pushing the button to select which interview to watch, the exhibit wasn't very interactive.



Nevertheless, "Cycles Stories" turned out to be a powerful exhibit: Ordinary people telling their own stories seemed to give visitors a personal way to connect to the abstract theme. Visitors said the exhibit helped them appreciate just how many aspects of life could be affected by cycles. One visitor commented:

"I thought integrating the concept of cycles into the everyday lives of people in every walk of life was great. It was cool that the tollbooth lady thought about the cycles of traffic. It really showed me about the importance of science concepts in ordinary life."

Boundaries: It All Happens at the Edge

In *Boundaries*, our next thematic presentation, we expanded the personal interactions available to visitors. The centerpiece of the exhibition was a demonstration area called the "Boundaries Bar"—a long, multiuser station that was continuously staffed. At the "Boundaries Bar," exhibit developers and staff scientists conducted demonstrations of some of the more complicated boundaries experiments. They also facilitated visitors' exploration of a variety of boundaries-oriented materials. A dozen different hands-on experiences were offered at various times during the day.

At the "Boundaries Bar," visitors could examine the twenty layers of a Kevlar® bulletproof vest (along with four bullets that had been fired into it); heat a space shuttle tile with an acetylene torch; compare different kinds of coverings, from a pine cone to an eggshell to a leather glove; and use a microscope to see the permeability of their own cheek cells.

During each of these experiments, staff members both answered visitors' questions and posed questions of their own: Where is the boundary? What can pass through? What can't? Each demonstration was a unique conversation, not a rehearsed speech given to visitor after visitor. This inquiry-based method of teaching reinforced the philosophy behind the Framework. And by allowing each visitor to tailor his or her own experience, it also reinforced the Exploratorium's pedagogy.

If we design exhibits that interest us, our visitors will naturally be interested, too.

"Hands-on stuff is a certain kind of interacting and questioning, playing with something, physically exploring, independent of anyone else. But when you start to talk about it with someone, your exploration may go off in directions you'd never have suspected."

—Jim Meador
Exhibit Developer

In the mediated area of the "Boundaries Bar," staff members were able to structure an experience and still allow a visitor's curiosity to shape it. Using the depth and breadth of their knowledge about the experiments, staffers were able to link phenomena from life sciences, physical sciences, and even social sciences to help visitors see how very cross-disciplinary a theme like Boundaries really is.

Systems and Interactions

Rather than create an exhibition and build human elements into it, we decided to present this theme entirely as a series of demonstrations and dialogues. Although this was a method that our Center for Teaching and Learning (CTL) had been using for decades, we hadn't tried applying it to a more casual audience.

Three teams (consisting of an exhibit designer paired with a teacher from a CTL program) each developed a floorwalk—an informal "minitour" and discussion of a few exhibits. At the beginning of the planning process, team members met weekly to discuss the best way to create the walks. They also tested the format's possibilities by participating in walks led by veteran staff members. They worked closely with the in-house evaluator to get feedback from visiting teachers taking prototyped floorwalks.

Over a period of a few months, each team chose three exhibits in different sections of the museum, and then they created and refined questions and activities that would model thematic teaching for those exhibits. Once the development process was complete, the teacher-designer pairs offered *Systems and Interactions* floorwalks to visiting field-trip teachers on weekday mornings. Teams kept the tours to thirty minutes—long enough to give the teachers a feel for the inquiry-based approach, but not so long that they felt they might be neglecting their students.

Each floorwalk was an inquiry-driven exploration of how systems work. At each exhibit, the team members asked the teachers a few simple questions—not to lead them to a particular answer, but to give them guidelines for focusing their curiosity: "What are the parts of this system? What do you think would happen if we changed this part? How about this one?" Instead of just giving the visitors facts, the floorwalk teams offered them a new way of using the exhibits and thinking about the world around them—the essence of the kind of education the California Science Framework advocates.

If we design exhibits that interest us, we may miss opportunities to find out what interests our visitors.

"Mediation provides a structure that can help teachers approach a mystery or a puzzle that they want to solve. And it's really hard to solve those mysteries unless somebody's there who's skillful enough to create a structure and a design and a context."

—Dennis Bartels
Director, Center for Teaching and Learning

As visitors answered those questions, they began to ask new questions of their own. The questions posed by individuals gave each floorwalk a unique character. Because of the human element, no two floorwalks were ever the same. Each person was able to approach the Systems and Interactions theme at his or her own level and shape the experience according to personal curiosity.

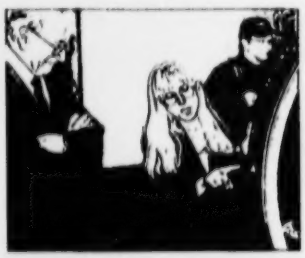
As one of the team members explained:

"If you're walking and talking with someone who knows a lot of interesting stuff, whether it's about physics or the world in general, you're going to find yourself fascinated by things that you might never have known existed. By yourself, you make one layer of discoveries. If you're with someone who knows that there are other layers, you can explore those, too."

Of the teachers we surveyed months later, one-third remembered the theme of Systems and Interactions and said that the floorwalks were a good introduction to a hands-on museum.

The teachers' positive reaction to the floorwalk format brought us back to an original Exploratorium model, but from a direction we hadn't anticipated. Our teacher programs have always used floorwalks as a way of modeling inquiry-based teaching, and staff members frequently take friends and special guests around the museum in this way. This project made us aware of the opportunities for using our exhibits as a basis for inquiry and exploration for the general public.

For the Exploratorium staff, rethinking our attitudes about staff interactions with visitors was one of the most important changes to come out of the Framework project. We rediscovered one of our greatest strengths—using the exhibits as starting points for inquiry and exploration. We developed new techniques for helping visitors frame their experiences, enhancing their ability to make their own connections and discoveries.



We are continuing to experiment with the floorwalk concept, considering how to best use this format for field trips and the general public.

If visitors know what to expect, they can have a more meaningful experience.

What We Learned About Floorwalks

- Floorwalks take several months to create and refine—significantly less time than it takes to develop a major exhibition.
- Because floorwalks use existing exhibits, exhibit development time and costs are minimal.
- Floorwalk leaders can focus visitors' attention on different parts of the exhibit, explaining any confusing or challenging elements.
- Floorwalks offer opportunities to explore exhibits in a manner not available to the casual visitor.
- Floorwalks are very powerful, connected, and thematically relevant experiences, but they can only be offered to a small number of visitors at a time. (For us, the ideal number of participants was six to ten per floorwalk.)
- Floorwalks require a high level of ongoing commitment in the form of both time and staffing. In contrast, an exhibition uses the bulk of staff time in the development process.

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If visitors know what to expect, it takes away from the excitement of exploration.

TEACHERS

"Ideally, I think we should invite teachers in a partnership, not a pedagogical relationship. Bring them in and say, 'This is what we have. This is what you have. Maybe we can help each other.' The floorwalks helped the museum as much as they helped anyone on the outside."

—Shawn Lani
Exhibit Developer

For almost thirty years, teachers have come to the Exploratorium to be renewed and inspired. In after-school workshops and summer institutes, they learn new skills and techniques and tricks of the trade, and find new ways to bring hands-on learning back to their classrooms.

As the California Department of Education's first Regional Science Resource Center, the Exploratorium has a long-standing connection with formal education on the local and national levels. Programs in our Center for Teaching and Learning (CTL) have provided hands-on training and professional development for thousands of K–12 science teachers. The Framework project offered us an opportunity to forge a very different kind of relationship with local teachers. We experimented with linking teachers, Exploratorium exhibits, and the standards and themes outlined in the California Science Framework.

Although we'd always used our exhibitry as "props" for hands-on teaching, inviting local teachers to be an integral part of the exhibit development process was an experiment for us. We wanted our exhibits to be relevant to teachers who were actually using Framework themes in their classrooms. So a central part of the project was creating a Teacher-Educator Working Advisory Group.

As we formed this group, we invited teachers who were current or former teachers-in-residence or CTL program alumni and were therefore already familiar with the museum and its exhibits. The volunteer teachers we selected, representing elementary, middle, and high schools, had many years of classroom experience and were active in leading professional development workshops in their districts. We also invited leaders in the science education reform movement and representatives from other California science centers to serve on the Advisory Group.

At the time the Advisory Group was created, the California Science Framework was a fairly recent document, and teachers were still actively working on the best ways to put Framework theory into practice in their classrooms. This made them ideal "translators" of the formal Framework document into more informal terms. Their struggles to transform the Framework into workable curricula became an asset when it came to planning hands-on demonstrations and workshops for the many family-oriented and professional events associated with the project.

At the outset of planning each of the four thematic presentations, a team of Exploratorium staff members met with the Teacher Advisory Group. They discussed which Framework themes to use as a focus and which existing exhibits best demonstrated each theme. These discussions led to an analysis of the "gaps" we needed to fill in order to cover the theme. The combined group then brainstormed possible new exhibits that might be developed to further illuminate and illustrate the theme, and also connect to existing classroom curricula.

Our original plan was to have a few teachers from the Advisory Group work with our exhibit developers throughout the process of creating, prototyping, refining, and building exhibits. This turned out to be impractical for a variety of reasons. The primary problem was time: most exhibit development occurred during the school year when both the classroom teachers and teachers-in-residence were fully committed to their other duties.

A second obstacle also involved time, mixed with a kind of culture clash. Thinking in an exhibit way is not the same as thinking in a classroom way. Some teachers felt out of place in the machine shop, and exhibit developers were unfamiliar with developing materials for a particular curriculum. We needed time to find some common ground and develop a common vocabulary, but we hadn't built that kind of time into the exhibition schedules.

As the Framework project progressed, we reassessed our strategies for involving teachers. We decided that the best use of their time and talents was in the planning stage of each exhibition and in the process of critiquing prototype exhibits. In between those two stages, we asked them to examine how they made thematic connections in their own classrooms—what worked, what didn't—and to share those insights with us.

A Question of Size

The Teacher Advisory Group participated in the initial brainstorming meeting for *A Question of Size*, then met with project staff about two months later to review exhibit models and prototypes. The goal of the second meeting was to have teachers evaluate the proposed exhibits in terms of interest, ease of use, and understandability, and gauge how well each exhibit contributed to the theme of Size and Scale.

This meeting turned out to be a productive one, but not without its share of tensions. Teachers' feedback on a few of the exhibits was less than enthusiastic. It wasn't that they weren't interesting exhibits, the teachers explained, it was just that what they demonstrated was a bit of a conceptual leap to the theme of Size and Scale—too big a leap for most teachers to make and certainly not a connection that students or the general public would be able to see.

Some of those exhibits were reworked to better

Teachers who visit the museum use exhibits to help inform their teaching.

"fit" the theme. Others were shelved, which upset exhibit developers. "It's a good exhibit," they argued. "It's an interesting phenomenon. It's nuts to drop it because it doesn't teach one particular lesson." But getting a thematic connection across was proving to be more of a challenge than we'd originally thought.

Cycles: Nature Repeats Itself

Before the initial brainstorming meeting for *Cycles*, Exploratorium staff had surveyed museum visitors, including teachers on class field trips, about what the word "cycles" meant to them. Using this input from the public, the Advisory Group tried to make connections between the theme of Cycles and classroom curricula. These efforts formed the basis for the development of the exhibit collection.

Working with project staff, the Teacher Advisory Group began assessing *Cycles* exhibit collection plans by examining the existing exhibits and brainstorming about possible new ones. The result of one staff and Advisory Group brainstorming session was an idea for a new exhibit that came to be called "Cycles Stories." The idea, implemented by staff exhibit developers working with a videographer, became one of the most popular and successful exhibits in *Cycles*.

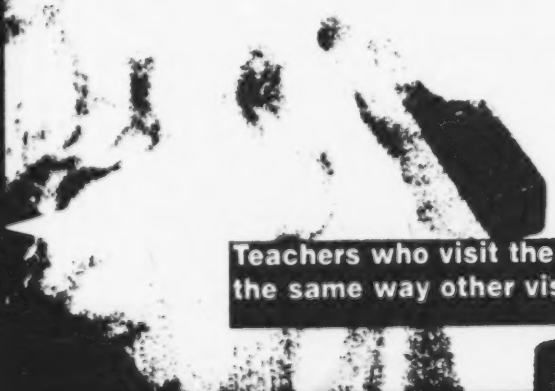
"Informal science education endeavors need to consciously couple their work to the needs of schools and families if they are to play a strong role in science and math education reform."

—Rob Semper
Executive Associate Director

Boundaries: It All Happens at the Edge

After *Cycles*, the Advisory Group met to discuss how we could use themes that went beyond the scope of the California Science Framework. We had discovered that many classroom teachers were unaware that the themes suggested by the document were not "set in stone," or that thematic teaching was not limited to the six themes specifically outlined in the Framework's pages. We wanted to use the third exhibition to model a broader view of thematic teaching, using the Framework as a starting point, not a destination.

Trying to decide what the exhibition theme would be was an interesting process. A few teachers on the Advisory Board were uncomfortable with the idea of creating a "new" theme. They argued that it was difficult enough for teachers to integrate thematic teaching into their existing curricula without the added complication of thinking up themes that were not on the state's "recommended" list. Other teachers were more receptive to the concept, but each had a different idea about what that new theme should be. The teachers considered the staff's list of top candidates, and, after much debate, agreed with the staff that Boundaries had the best potential.



Teachers who visit the museum interact with the exhibits the same way other visitors do.

Systems and Interactions

As we developed the first three Framework exhibitions, we kept running into problems making thematic material accessible to teachers and students from a wide range of grade levels. To resolve this dilemma in our fourth Framework project, *Systems and Interactions*, we decided to give grade-appropriate floorwalks for field-trip teachers visiting the museum.

Of all the Framework experiments, this project was the most successful in terms of teacher/staff collaboration. A select group of teachers was temporarily hired to help develop the floorwalks. (The teachers involved were retired or on sabbatical from their districts.)

Three teams were created to design floorwalks for elementary, middle school, and high school teachers. The teams were responsible for choosing three exhibits and then developing a half-hour-long "walk and talk" that demonstrated the theme of Systems and Interactions.

After about six weeks of development, the teams gave floorwalks on weekday mornings for two months. Teachers calling to make reservations for field trips were told about the opportunity to take a floorwalk and asked if they'd like to participate. We also offered teachers the opportunity to participate as they arrived on the day of their field trip.

Because the "audience" for the floorwalks consisted of any interested teachers who happened to be at the museum that day, it was often an eclectic mix of grade levels. For instance, one tour that had been designed for the elementary school level had three middle school teachers and a mixed-grade (2, 4, 7, 9) teacher. A "high school" tour had two elementary school teachers and a student teacher from a local college. The only area where age specificity came into play was at the end of each floorwalk, when we gave teachers packets of grade-related activities to take back to their classrooms.

Each floorwalk used three existing exhibits, each of which remained situated in its "home" area on the museum floor. One floorwalk focused an exhibit that dealt with ecology, an exhibit on air pressure, and an exhibit on linguistics. Another team combined the same air pressure exhibit ("Bernoulli Blower") with an optics exhibit and an exhibit about motion and momentum. By using exhibits that were scattered throughout the museum, the floorwalks helped reinforce the idea that themes can connect disparate phenomena.

Many teachers interviewed after taking a floorwalk said that the most valuable part of the experience was the way the process of inquiry and hands-on learning was modeled. One teacher commented:

"The team leaders asked us questions: 'What are the parts of this system? How do they work together?' And we all discussed the questions. The information I got was interesting, but what I came away with was thinking about how I could use that kind of teaching with my own students."

Teachers are interested in theme-based teaching.

"The Framework project posed a new idea: 'Let's combine the formal and the informal and remold exhibits on the floor so that they become useful for teachers.' Part of the incentive was that teachers didn't appear to know how to deal with themes, so we decided to approach themes as they related to phenomena."

—Thomas Humphrey
Senior Scientist

The Framework project was an experiment in linking formal education with an informal science center. It was an opportunity for the museum to think about pedagogy and curriculum in the course of designing exhibits. Dennis Bartels, director of the Exploratorium's Center for Teaching and Learning, summed it up:

"It was fascinating to watch what we'd originally thought of as an exhibition-based project evolve into something much more like our teaching programs. It reaffirmed for me that the most powerful work we can do to link schools and informals is through those kinds of structured programs, using our exhibitry as the medium for making connections."

Teachers are interested in figuring out how to teach—despite the demands of theme-based teaching.

POLITICS

"Schools need to have neighbors, friends to help them in the process of change. In informal institutions, teachers and families can come and see what's new in science, and can interact with hundreds of exhibits."

—Goery Delacote
Executive Director

"There needs to be a bridge between schools and informal science centers. Our strongest role is in creating exhibitions and programs, so that schools can come to us, use our methods as a model."

— Kathy McLean
Director, Center for Public Exhibition

Science education reform has always been an integral part of the Exploratorium. When he began the Exploratorium in the late 1960s, founder Frank Oppenheimer wanted to provide a hands-on alternative to the didactic way science was being taught in most classrooms at the time. Today, members of the museum's Center for Teaching and Learning are active in reform efforts at the local, national, and international levels. Executive Director Dr. Goéry Delacôte works to further reform efforts as a member of the National Academy of Sciences' Committee on Science Education Standards and Assessment.

Any reform, by its nature, involves change and controversy. In writing a grant, the lag time between when the proposal is formulated and when it's implemented can be several years. When the grant itself involves an area that's controversial or politically au courant, there's an additional risk that the winds of change will have blown some ideas right off the cutting edge by the time the project is completed. Ideas such as thematic teaching, for example.

The success of this project depended on two broad factors, one under our control, the other outside it. First, we hoped that the exhibitions would be resources for classroom teachers and models for other science centers who might want to create standards-based exhibitions or programs. By using the California Science Framework as a basis for our exhibitions, we had to grapple with what was meant by a theme before we could get down to the task of developing strong exhibitions to get those themes across. Not a simple task, but we were ready to tackle that challenge. The second factor, however, threw us for a loop.

Through the evaluation process, it became painfully clear that few people agreed about what themes were, how to teach with them, or whether they were really a viable way of organizing ideas—in classrooms or in informal science centers. By the time we opened our third exhibition, *Boundaries*, some of our advisory teachers, whose schools had been district models for theme-based curricula, had abandoned the idea of teaching with themes entirely.

In a debriefing meeting at the end of the project, Dennis Bartels, Director of the Center for Teaching and Learning made the following observation:

"Any grant proposal is a working hypothesis for an experiment that has not yet been done. As the experiment is conducted—the exhibition mounted, the program developed—flaws in that hypothesis become apparent. But part of the scientific method is that as data come in, you revise your hypothesis and continue to experiment. That's how learning occurs and science progresses."

The Framework grant was written to support three of our interrelated, long-term goals: becoming a

"It's interesting that museums are involved in a movement to reform the schools. I don't see schools involved in a movement to reform museums."

—Symposium Participant

more active partner with local schools, playing a more vital and multilayered role in supporting science education reform, and reworking some existing exhibits so that they better support thematic teaching. Refurbishing existing exhibits not only improved the overall look of the museum floor, but also made the project much more cost-effective, since the exhibit development process didn't have to start from scratch. That left us with more time to focus on the meat of the grant and of the Framework: presenting the "big ideas" of science in ways that would inform both teachers and the public and encourage them to explore these ideas further.

But this process has also had other unexpected benefits. The standards-based reform movement has provided many of our teaching and other long-standing educational programs with the direction, focus, and validation that have allowed us to work in cooperation with schools. After all, we're all part of the same global effort toward science literacy. Our first-hand knowledge of the standards has enhanced our credibility and made many relationships with outside partners easier.

At the end of the Framework project, we held a national symposium, inviting colleagues from informal science centers, educational institutions, and others working in the field of science education reform. The three-day gathering allowed us to share some of the results of our experiments—both the successes and the dead ends—and to create an environment in which participants could think and speak freely, learn from each other, and grapple with key issues.

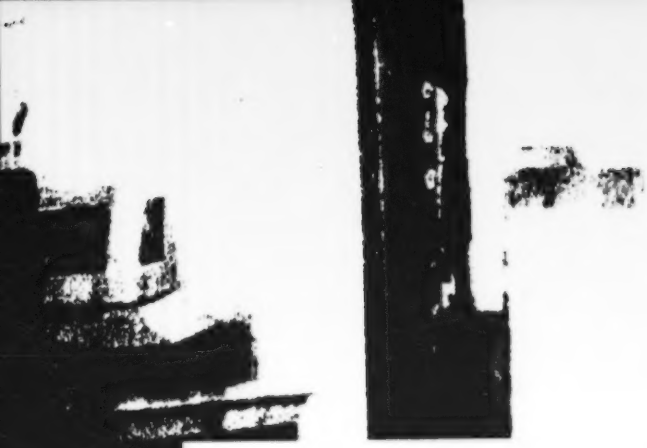
Several observations about the field emerged at this symposium. First, we recognized an understanding that school reform is very complex and, as a result, our responses to the needs of formal educators are growing more sophisticated. Second, we acknowledged that, across the field, there exists a diversity of uses—and even of interpretations—of standards documents such as state frameworks or the 1995 *National Science Education Standards*. Third, we realized that whenever the conversation appeared to be zeroing in on standards as blueprints for science education improvement per se, it quickly veered away to more general topics about museum work with schools.

It is this last observation that is perhaps the most curious and telling. It may indicate that—as it was at the Exploratorium for the life of the grant—state frameworks and standards challenge our comfort zones, suggesting that we might have to give up some assumptions and degrees of freedom to be more deeply involved in the science literacy effort, particularly where we work with, and in, schools. Or it may point out, as was also the case at the Exploratorium, that we are only now becoming intimately familiar with these standards documents: that they are not yet in our bones. We have not argued over them and fretted about them and analyzed how we as science centers might have to change if we took them more seriously.

Because of this grant, we at the Exploratorium had the opportunity to spend hundreds of hours arguing over the meaning of the California Science Framework and its notions of theme-based learning. If nothing else, the discourse that has begun may be a significant accomplishment in itself.

Standards documents are as much political

Informal science institutions get diverted from what they do best when they get involved in education reform.



"Parent involvement in education has always been important. And this benefits museums. Where do you think those parents are going to take their kids?"

—Symposium Participant

statements as they are educational documents. They embody assumptions and values about who can learn, how they learn, and what is important to learn. This makes these tools of reform both powerful and controversial, for both schools and museums.

With the Framework grant, we were thrown into unknown territory, and that forced us to take some long, hard looks at what we did and how we did it. At the debriefing meeting, staff participants listed nearly a dozen areas in which the museum as a whole experienced incredible growth in the ways we thought about our work.

We challenged our notions of what we present to the public, and how. We reexamined and redefined our audience. We experimented with large-scale thematic exhibitions and with new kinds of graphics. We tinkered with our exhibit development process. We experimented with environments and contexts and mediated experiences. We tried new ways of collaborating with teachers and formal education.

Informal institutions have a unique opportunity to reach large numbers of parents, even briefly, as well as teachers and students. Through exhibitions, take-home materials, Family Nights, and other programs, we strove to introduce parents to current events in science education reforms, demonstrating that science teaching doesn't have to be didactic, and that learning can (and should) be active, fun, hands-on, and inquiry-based—without sacrificing any of "the basics."

We knew that some of the parents who attended our Family Nights might also be volunteers in their children's classrooms; others might belong to the PTA, or go to school board meetings. Whatever their level of involvement, our hope was that they would take with them the seeds of ideas learned at the Exploratorium, and perhaps even become advocates for a different kind of science teaching than they had experienced when they were children.

Through this project and other programs, we also sought to create tools and strategies for teaching professionals who may not have had the opportunity to participate in our weeks-long, intensive teacher institutes, but who may have wanted to introduce inquiry-based learning in their classrooms. Some of them, we hoped, might come to our other workshops, recommend them to colleagues, or seek out the offerings of other institutions. Others might become science resource teachers for their schools or districts. And still others might serve on curriculum committees and influence the kinds of textbooks and materials their districts adopt.

Eventually, voices trickle up—from parents and individual classroom teachers to schools to districts to states. Ideas become documents, standards, frameworks, policies. And all of those, in turn, eventually trickle back down, to the museums whose programs support those standards, and to the schools that implement them.

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Informal science institutions should embrace and support education reform.

PERSONAL PERSPECTIVES

In October 1998, Exploratorium staff presented "The Framework Exhibit-Development Project: An Institution-Changing Experience," at the annual conference of the Association of Science-Technology Centers in Edmonton, Alberta, Canada. The excerpts below, taken from the presentation, express the hopes and frustrations of five people with different responsibilities in the Framework project, their varying experiences, and points of view.

Thomas Humphrey: Senior Scientist

The Framework project was an exercise in comparisons and tensions, but the one element that always loomed larger than the rest for me was the study of the relationship between thematic exhibitions and inquiry-driven exhibits—similarities, differences, and compatibility.

While thematic exhibitions may have more than one purpose, one among them seemed to have precedence: We wanted visitors to walk away from the exhibition with an understanding of the theme presented. We wanted them to feel that exploring a theme was worth their effort, and we wanted them to possess a new (or renewed) realization and appreciation of thematic connections in nature.

On the other hand, inquiry-driven exhibits are more process-oriented. We tried to design the phenomena in these exhibits to produce an almost immediate response that is more affective than intellectual. The context in which these exhibits stand is not a narrative context of the cultural or historical kind; the context is an inquiry-supporting one, created by the design of the exhibit, including graphics and text, and the space within which it stands. The goal of the context is to create an environment in which visitors find it natural to question and experiment. These exhibits are designed to be layered, which means that they are designed so that there are discoveries to be made.

This, in itself, is hard enough to achieve, but we have an ideal that goes beyond this description. Inquiry-driven exhibits are by nature learner-centered. It is our hope that after many experiences with such exhibits, visitors will be more disposed to the exercise of inquiry in their lives outside the Exploratorium.

Every inquiry-driven exhibit is a part of many thematic explorations because inquiry is bottom-up. Thematic exhibitions are top-down. An evaluator assessing theme-based exhibitions might ask visitors, What did you learn today? Did you learn what I wanted you to learn? An evaluator assessing inquiry-based exhibits might ask, What questions came up for you today?

Thematic exhibitions create the concept of extraneous and distracting elements in an exhibit; that is, those that might divert the visitor from learning the goal at hand: the theme. There is continuing debate over whether reducing the number of elements in an exhibit is "dumbing down" or increasing focus. At the Exploratorium, there are champions of both thematic exhibitions/programs and inquiry-driven exhibits. The relationship between these two is still being debated.

Kathleen McLean: Director, Center for Public Exhibition

I arrived at the Exploratorium just as we'd learned that we'd received the NSF grant to do the Framework project. A majority of the project fell within the Center for Public Exhibition, which is my area of responsibility.

I brought with me to the Exploratorium twenty years of exhibit development experience. But it was experience developing very different kinds of exhibits and exhibitions (more thematic and topical—focused on exhibition environments, and more multidisciplinary, combining arts, sciences, history, and narrative.) This means I brought some different insights and biases with me to the project.

For me, this project was designed with many moving parts—ambitious goals, dozens of different miniprojects, heavy expectations from NSF program officers and grant reviewers, and lots of assumptions.

I had concerns about the project from the beginning. First, I knew that if we were going to explore

the notion of thematic exhibitions, we would have to profoundly change the way we thought about and developed exhibits, and the way we related to our visitors. I still believe this—and although we did change our relationships with visitors during the course of the project, we didn't go far enough or deep enough in experimenting with new exhibit development techniques to test the possibilities of thematic exhibitions. We approached the project using the "exhibit collection" model—a group of individually designed and conceived exhibits placed side by side. Collections of exhibits are usually intended as discreet individual experiences without the constraint of communicating "big ideas," messages, or themes. This is a powerful way of creating exhibits—one of our best.

We needed to approach the project using the exhibition models—intended as environments that embody big ideas or themes (and usually containing individual exhibits as well). This is a powerful way to provide context, conceptual frameworks, and narratives that are essential to communicating abstractions.

I didn't agree with the assumptions about audience—that teachers and the general public were the same, needed the same things, accessed and interacted with our exhibits in the same ways (particularly if the exhibits were meant to help teachers use the Framework-mandated thematic approach to teaching). I learned that, in terms of understanding our exhibits, teachers really are like the rest of our visitors, even with their teacher hats on.

I have always felt that what we do best in informal environments—the exhibits and programs and experiences we provide—are fundamentally different from the experiences provided in schools, and that we shouldn't try to design our exhibits and programs to fit formal educational constructs. We spent an awful lot of time trying to create hybrids that, in the end, were very constrained.

My overall assessment? The most significant aspect of the project was the process we went through of grappling with themes. This is probably very parallel to the process teachers have to go through in order to teach thematically.

Our major concerns centered around these questions:

- What is a theme, anyway?
- How can I fit what I've always been doing into this new framework?
- If I can't fit what I've been doing (successfully) into this new framework, what must I change? What must I give up?

And, finally,

- Is it worth it?

Our most valuable effort for the field, I believe, was in documenting our process of grappling with these issues and articulating the tensions between the abstract, top-down, deductive approach, and the concrete, bottom-up, inductive approach. Both are valuable—even necessary—ways of thinking about and experiencing the world. Our challenge was to articulate their appropriate applications and understand their differences.

Sue Allen: Director of Visitor Research and Evaluation

I was quite excited about this project because it focused heavily on science learning, a particular interest of mine. I should admit that I was something of a skeptic with regard to themes, but I felt that this was an opportunity for us to see if they could be powerful ways of thinking, as the Framework suggested.

Once I joined the project, I discovered that the developers had a tradition of watching visitors use exhibits, but that they didn't do systematic interviews. They'd chat with visitors and engage them in a wonderful mediated experience that was great for the visitors, but it didn't help me understand where the problems were.

Also, some of the developers seemed to be pushing the exhibits in a direction that didn't make sense to me. They would work long hours to make exhibit prototypes more beautiful and compelling, even when conversations showed that visitors didn't see any connection to the theme. One developer said: "I guess the 'Stress Bridge' isn't exactly about scale, but it's

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about the larger theme of scale and structure, and it's really cool . . . and I heard someone talking about the exhibit and how he'd worked in construction, but he'd never seen stress before."

To me, this seemed at odds with our goal: Weren't we supposed to be teaching the themes of science? Wasn't that the number-one goal of this project? Clearly, we were both trying to improve the exhibit, but we had different values in mind. The developers were putting their energies into making a really compelling visitor experience that might inspire someone to get deeper into the material, and I was putting all my energies into getting the theme across, sacrificing any other aspects of the visitor experience if necessary. No wonder we were all frustrated.

When I think about where this project changed us as an institution, I think it changed the way we do evaluation and how we think about it. By the end of the project, developers and other members of the teams had become much more receptive to evaluation generally, and to interview questions in particular. At the same time, I had become more savvy about the importance of creating a compelling exhibit experience.

Actually, the fact that the project was about themes turned out to be unexpectedly helpful in moving us forward. With something as abstract as a theme, you can't tell if someone "gets it" unless you interview them; just watching isn't enough. So we started talking regularly to visitors. And once we could all get together and look at what visitors were saying, we started having great arguments: about what constituted thematic understanding and what didn't; about what constituted learning and what didn't; about what was a great exhibit experience and what wasn't. Those conversations have carried forward into our other projects, and have given us new ways of seeing exhibits, and a common language with finer discriminations for talking about them.

We also learned the value of basic front-end evaluation in thematic exhibitions. Our first exhibition, *A Question of Size*, was entirely based on the concept of scaling, and how length, area, and volume change in relationship to each other when an object is scaled up or down. It was only very late in the process that we realized most visitors didn't even make clear distinctions between length, area, and volume as ways of describing size. After this discovery, we did basic front-end evaluation on all our other exhibitions.

We also learned that getting an exhibit to be about an abstract theme is hard, no matter what your exhibit label says. For example, we renamed one exhibit "Bike Cycle," and emphasized the cycle of steps in the sequence of pedaling a bicycle, but visitors still said it was about robots and leg muscles.

At the exhibit "In the Land of the Ants," we used blue-screen technology to merge a large image of an ant colony with images of our visitors. We encouraged visitors to think about scale by comparing their weight-lifting abilities with those of the ants, but visitors mostly saw the experience as a great photo opportunity.

We built the exhibit "A Drop to Drink," in which visitors manipulated a doll's hand holding a tiny cup, and found out how difficult it was to get the water to pour out. Our label explained that surface tension is a dominating force for creatures below a certain size. Most visitors experienced the exhibit as showing how sticky water is, but they missed the more abstract scaling idea and its implications entirely.

We learned that visitors may, if asked, be very creative in finding connections between a particular exhibit and a particular theme; however, this doesn't necessarily imply that the exhibit will suggest the theme when it stands alone.

For example, for the *Boundaries* exhibition, we considered using the exhibit "Everyone Is You and Me," in which two visitors merge their faces by adjusting the light levels on two sides of a pane of glass. When we asked visitors "Do you see any kind of boundary in this exhibit?" many said they did. However, it turned out that they perceived a wide variety of boundaries, including the glass between the people, the frame around the glass, the edges of the faces, the limits of what you can see, the identity boundary between people, and even how many people could use the exhibit.

We also learned that visitors won't easily deduce the abstract theme from a collection of exhibits on different topics. For example, when we were prototyping our early collection of Cycles exhibits, I asked visitors: "Do you see any connection among these exhibits, any kind of common idea or theme?" Visitors responded:

No.

Yes, movement.

Yes, mechanical things.

Yes, patterns/ the body/ weather/ nature/ astronomy/ scientific ideas/ how things affect each other/ etc.

We learned that pushing two exhibits together suggests a commonality, but not what that commonality is. In the "Vinegar Eels/Arawana" exhibit, our label explains why large fish can glide more easily through water than tiny vinegar eels, but visitors thought the connection might be that big fish eat little fish, or maybe that the little vinegar eels evolved into the big fish.

Inverness Research Associates, who did all our summative evaluations, helped us learn about the overall impact of our exhibitions. One of the things we learned was this: If you yell the theme with big signs, you can get it across to the majority of your visitors, but it tends to be quite superficially understood (for example, the *Boundaries* exhibition) or not perceived as profound (for example, the *Cycles* exhibition). Mediated experiences and personal narratives seemed to be more effective ways to get a thematic message across to visitors, as well as to teachers.

Erik Thogersen: Exhibit Developer

I came into this project with some strong opinions about what sort of exhibit does the most for visitors. My taste seemed to jibe well with that of many of the other developers at the Exploratorium.

We wanted to build engaging exhibits based around intriguing or beautiful phenomena. We thought that a great exhibit would lead visitors to questions and experiments, and that learning would come from directly experiencing the phenomena. My own bias was that informal science centers should focus on encouraging inquiry, and making that inquiry fruitful, rather than on achieving specific learning goals. Our goal in the Framework project, however, was to build exhibits that led visitors to understand an abstract theme. That was a challenging task—all the more so because of our biases about what makes a good exhibit.

As a result, one of our greatest frustrations was that we had to make choices about which exhibits to build and how to build them based on the need to get the theme across, rather than on how compelling the exhibit seemed. For instance, in our first exhibition, *A Question of Size*, one exhibit developer created an exhibit called "Expando Cube," but had to give up the cool materials that made the exhibit engaging so that it would be about scaling.

In our second collection, *Cycles*, we had similar frustrations. A round case and a picture of a rooster may not have made the "Chick Embryos" exhibit about the cycle of life, but it was still about the very cool experience of seeing a beating chick heart. We wanted people to get the theme, but we refused to take anything away from the exhibits. Nearby, in "Cycles Stories," we presented video stories with all kinds of people talking about the cycles in their lives. This was probably the most effective exhibit in the collection. But, for an exhibit developer, saying that "Cycles Stories" works and "Chick Embryos" is a failure is scary, since the latter is a great exhibit experience, while the former is TV.

In the third exhibition, *Boundaries: It All Happens at the Edge*, we took exhibit development in a new direction: minimal text; no discussion of non-boundaries phenomena; an attempt to get people to experience boundaries directly.

In *Systems and Interactions*, we did nothing to the exhibits, but instead sent developers onto the floor to drive home the theme in person. At first I thought, "We're exhibit developers; now we seem to be tour guides." In the end, we had a great time and

learned a lot about teaching. This was our first really tight collaboration between exhibit developers and teachers, and that interaction proved one of the most fruitful aspects of the project.

This project pushed us to think deeply about the primary experience of an exhibit. We quickly learned that our attempts to change that experience—to, in essence, change what visitors get out of an exhibit with lots of text, huge posters, and grand icons—was feeble indeed.

We have reaped long-term benefits from better understanding the visitor experience. In our new projects we are being much more explicit about defining the primary experience we want visitors to have, and checking to be sure that we are successful in providing that.

We learned that a powerful exhibit on a phenomenon almost always seems to be perceived as being about that phenomenon, and not about some secondary abstract quality, even if that quality is profoundly there, and even if we highlight it with flashing lights. To be truly effective, I now believe that the most interesting and compelling aspect of a thematic exhibit needs to be the theme itself.

Dennis Bartels: Director, Center for Teaching and Learning

I arrived at the Exploratorium halfway through this project, so I was not a part of its conception or the assumptions going in. But I had come from being the principal investigator of the NSF State Systemic Initiative in South Carolina, where I was also responsible for helping develop state curriculum frameworks. I have to disclose now that I was, in part, responsible for pulling together the 1990 California Science Framework, which suggested that themes were the way to go. So, talk about coming full circle!

When I began working on the Exploratorium's Framework project, I found the museum staff asking the very same questions teachers were asking: What is a theme? Can I fit it in with what I'm already doing? If not, what do I need to change? And finally—and I think this is a very legitimate question—is thematic teaching worth it? We spent thousands of hours arguing about that at the Exploratorium in the process of implementing this grant. But how can classroom teachers, who face no less daunting a task, take thousands of hours to argue about the thematic approaches advocated in the Framework?

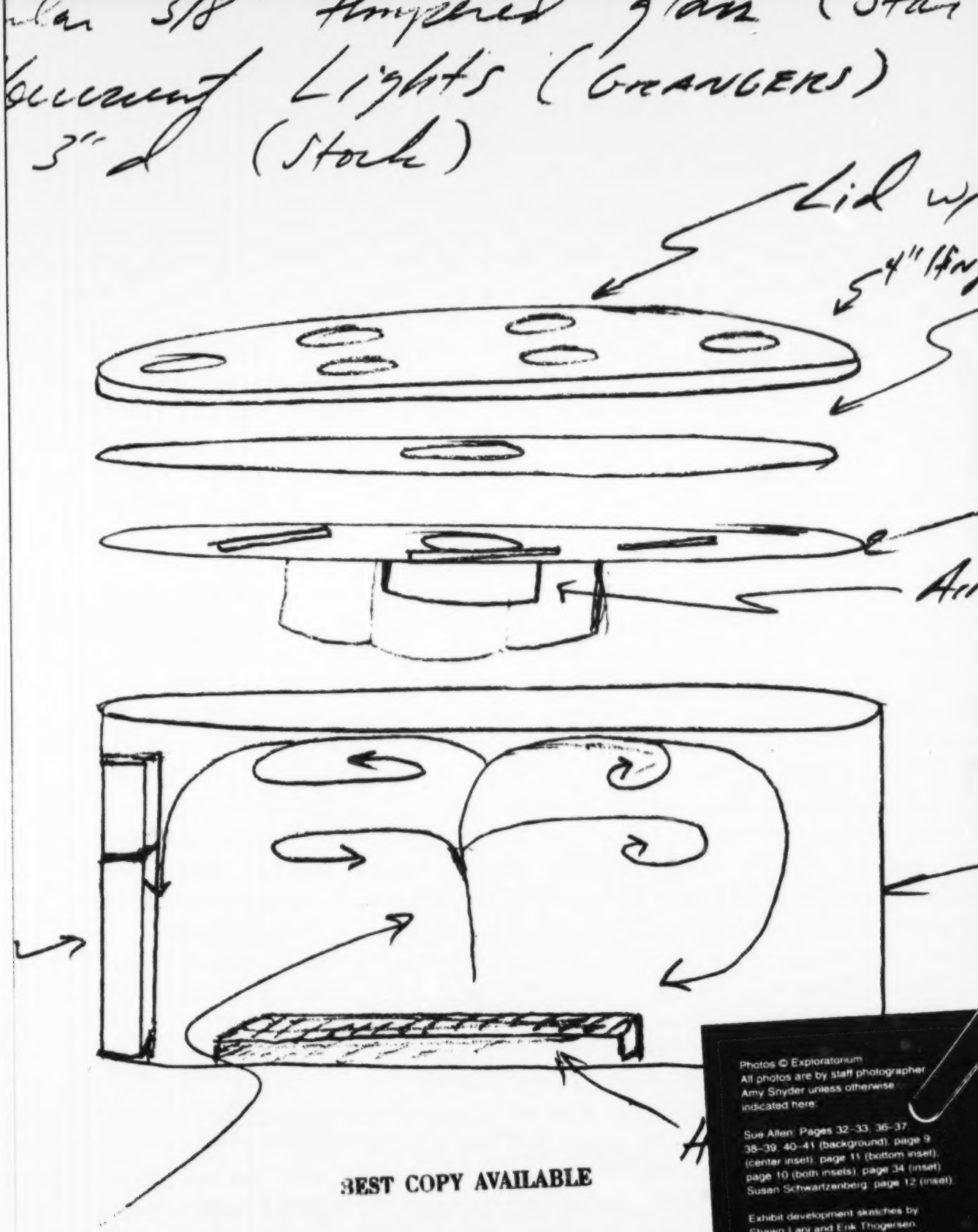
In the Exploratorium Teacher Institute, we encourage teachers to pursue their own mysteries and puzzles on the museum floor. However, these experiences are carefully structured by our staff. Because of this, our programs have always been very successful in helping teachers develop a first-person relationship with science. They help teachers move from thinking of science as something that other people do to something they can do themselves.

So how can you accomplish that kind of transformation by just having a brief encounter with an exhibit, without any other personal interaction? How can a teacher on a field trip see these exhibits and suddenly, profoundly, decide "I'm going to go back and change my whole curriculum"? It's no surprise that, as we worked, each successive exhibition included more staffed activities and resembled our teaching programs more and more.

We bet on the wrong horse. We really did. In the time it took for us to receive this grant and develop these programs, themes had already come and gone in California schools. For most classroom teachers, it was already a moot issue. Even our teacher advisors were telling us that.

Still, some people were disappointed that the informal science field as a whole did not rise up and immediately embrace the standards and say "These are ours; we can help students, teachers, and schools implement them." In reality, we, the informal science community, also needed time to think about these ideas, argue over them, and test them for ourselves, before we could extend meaningful help to others.

Is thematic science teaching a bad idea or a good idea that we just haven't implemented well? After four years, I still don't know the answer.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Sue Allen: Pages 32–33, 36–37, 38–39, 40–41 (background), page 9 (center inset), page 11 (bottom inset), page 10 (both insets), page 34 (inset).
Susan Schwartzenberg: page 12 (inset).
Exhibit development sketches by Shawn Lani and Erik Thogersen.

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